RAILWAY TRACK AND TRACK WORK.

By

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PREFACE.

IN view of the importance of the railway track which carries the enormous railway traffic of the United States, and in view of the amount of engineering and technical work involved in the construction and maintenance of the track, it may appear somewhat strange that the technical literature on the subject should be so limited. The first practical and comprehensive book on track and maintenance work as a whole was "The Roadmasters' and Section Masters' Guide," written in 1871 by Mr. W. S. Huntington, and revised and enlarged some years afterward by the late Mr. Charles Latimer. This was followed in 1886 by "Track," written by Mr. W. B. Parsons, and this book had a very extensive sale, but has now been out of print for some years. This book is familiar to every engineer on railway work, but its scope was somewhat limited, and in many respects it is now behind the times. Probably the only other comprehensive work on the subject is "The Trackman's Helper," written by Mr. J. Kindelan, being a practical book intended specially for the use of section foremen. It is true that there is a fairly extensive, but scattered, literature consisting of books and pamphlets on various individual details of track and track work, but the majority of these have only a limited circulation, while the men who have collected a number of such works have rarely the time or opportunity to study and digest them.

For these reasons, and from the fact that inquiries are being continually made for a modern comprehensive book on track work, it appears that there is a large field open for the introduction of a work of this character, and it is to meet this demand that the present book on "Track and Track Work" has been prepared. The aim of the writer (who is the author of

other works on matters connected with railway track and its improvement) has been to treat the subject as comprehensively as possible. The book, therefore, includes not only the systems which are everywhere applicable, and the general principles underlying track work, but also includes the numerous details of material, appliances and work, and the various methods of practice, which vary on different roads and in different sections of the country. It is thus fully representative of modern practice and standards on railways in all parts of the country. The various subjects included are treated not merely in a descriptive but also in a critical manner, with remarks upon the advantages and disadvantages of individual appliances and methods of work. A glance at the table of contents will show the general scope and arrangement of the book.

It would be impracticable to mention each and every railway officer and manufacturer of railway material who has furnished information to be made use of in this book, but the author takes the present opportunity to extend thanks for all information furnished.

E. E. RUSSELL TRATMAN.

New York City, January, 1897.

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PART I.—TRACK.

CHAPTER I.—INTRODUCTION.

The railway system of the United States now aggregates about 181,000 miles of railway, with 237,000 miles of track. The traffic over this system amounts to nearly 800,000 train miles in a year, while the importance of the railway service to the community at large is shown by the fact that about 1% of the total population is employed in this service. It will be at once seen that the maintenance of 237,000 miles of track to keep the railways in normal condition for traffic is a stupendous work, and one which affords great opportunities for the exercise of good judgment and executive ability in combining efficiency and economy in the conduct of the work.

The track upon which all the traffic has to be carried is one of the most important essentials of a railway, and yet the importance of the track and track work in their relation to the operation of the railway, and the proportion which the expenditures on track maintenance bear to the total operating expenses, are not as generally recognized as they should be, even by railway officers.

To many men the track consists of two lines of rails laid upon wooden cross ties; and the track work consists in attending to the spiking and bolting of the rails and the occasional tamping of the ballast under the ties. A glance at the table of contents of this work will suffice to show the variety of items included in track equipment, and the variety of the work required to be done in keeping the track up to condition for the traffic. In addition to all this, however, account must be taken of the care and forethought involved in devising the best and most economical materials to be used, and the best and most economical methods of conducting the work under the various conditions of construction and operation which prevail on different railways. The bridges, stations, locomotives, cars, etc., are all prominent features, and attract more or less attention for praise or blame as to their condition, but the track is rarely in evidence and receives little thought from the passenger or the average man, except when its particularly bad condition attracts attention by causing a noticeably uncomfortable motion to the train. In too many cases, also, it is taken for granted that any laborer not specially good for any other work can be properly employed on the track, it being assumed that when once the railway is built there need be but little work done upon it to keep it in condition, although it is almost universally recognized that a considerable amount of skilled labor is required to keep

the motive power and rolling stock equipment in condition for safe and economical service. It is, therefore, desired here to call attention to the importance and responsibility of the work of the engineer of maintenance of way, the roadmaster, the section foreman and the section men, and to the relation of their work to the operation and financial conditions of the railway.

The proportion which the charges for maintenance of way and structures bear to the total operating expenses of American railways is usually high, and this is due in large measure to the fact that a majority of the roads have been built in the first place with regard to immediate cheapness of construction rather than to ultimate economy in operation. The conditions under which the railways have been built, often in advance of the prospective traffic, have, on the whole, fully warranted the carrying out of the work on this principle. On the other hand, however, in too many cases the mistake has been made of allowing the original style of construction to remain unaltered and unimproved long after the traffic has exceeded that originally provided for. The result of this is that the road has to sustain an undue continual charge for maintenance. In fact, except on the main tracks of the large trunk lines, the conditions now prevailing are but little changed from or improved upon those which obtained in 1856, when Holley and Colburn in their excellent work on "European Railways," presented strong facts and figures to show that the greater economy in maintenance expenses on European railways was due in the main to the permanent character of the construction and the important part which was played by the civil engineer. To quote from that book: "The construction account can never be closed until our railways are *built*. To attempt it only involves a destruction account of fearful magnitude. Under our present system we are perpetually rebuilding our railways, not reaching the 'life' of our works, and thereby running capital to waste. A better system will strike at the root of this evil by correcting, not nursing, the defects of our permanent way (track)." It was pointed out that works which eat themselves up in expenses as fast as do many of those in this country must be founded on a low standard of engineering. This was considered to have been due to the main desire having been to do the most work for the least money (without much regard to the quality of the work done), and to the failure to recognize the value of good engineering skill. The extravagant maintenance expenses were characterized as "a reproach upon our civilization."

Allowing for the facts that these remarks were made 40 years ago, and that great improvements have been made in recent years, and also allowing for the difference in conditions in this country and in England (or in Europe generally), it must be admitted that there is even now far too great a proportion of our railways on which the enormous drain for maintenance expenses could be and should be stopped by large direct expenditures for permanent work and improvements if the economic principles involved were properly understood and carried out.

As shown by the brief summary of statistics at the end of this chapter, the traffic on all the railways of the United States for the year ending June 30, 1895, aggregated 766,856,853 train miles, and the operating expenses amounted to 67½% of the gross earnings from operation. The largest item in the expenditures for operation is that of "conducting transportation,"

which includes all train and station service, and this was 60% of the total expenditures, while the expenses for maintenance of way and structures amounted to 20% of these total expenditures for operation. On analyzing the details of these figures it is found that repairs to roadway aggregate 10.3% of the entire operating expenses, while tie renewals aggregate 3% of the same expenses. A consideration of the fact that the maintenance work on track and structures absorbs 20% of the operating expenses, and that half of this is for ordinary roadway repairs (exclusive of rail and tie renewals, etc.), will show the relation which the management of the maintenance department bears to the financial affairs of the railway company. Bearing this in mind, it becomes evident that great importance should attach to the proper management and conduct of this department.

These general averages for the railway system as a whole serve to indicate the general trend of the proportion of expenses, but they are of little use for application to individual cases, and railway officers should have such statistics worked out and recorded for their own lines. Few figures are available as to the actual relation of maintenance-of-way expenses to the financial affairs of individual railways, but from some such figures it appears that from 1890 to 1895 the expenditures on maintenance-of-way, included in operating expenses (and exclusive of any such expenditures charged to the capital account), averaged from $600 to $1,000 per mile of railway per year, or from 17 to 25% of the total operating expenditures, and from 10 to 17% of the total expenditures. These figures are only approximate, owing to differences in methods of making up such accounts and in the items included, as well as to differences in conditions of track and traffic. The following figures were given by the author in a paper on "The Relations of Track to Traffic on American and Foreign Railways," read before the New York Railway Club in December, 1896:

	Cost of Maintenance-of-Way Per Year.	
	Per Mile of Road.	Per Train-Mile.
Railways.		Cts.
Pennsylvania Lines	$2,600	8.895
Fitchburg	1,509	—
Vandalia (main line)	1,400	—
Columbus, Hoc. Vall. & Toledo	763	—
Delaware, Sus. & Schuylk	633	15.4
Pitts., Shen. & L. Erie	615	16.0
Louisv., Evansv. & St. Louis	619	—
Colorado Midland	612	—
Chi., Burl. & Kan. City	600 to 1,000	—
Grand Trunk	575	—
Phila., Read. & N. Eng	550.76	11.495
Chicago & Northwestern	541.90	19.0
Canadian Pacific	469	23.0
Chicago & W. Mich	303:76	10.5
International & Gt. Northern	26	—

A defect which is common to a large majority of railways is the lack of proper relation of the track to the traffic which it carries. Train loads, wheel loads, speeds and number of trains have in many cases steadily increased, while at the same time little or nothing has been done to improve the track in proportion to the extra strain and wear to which it is subjected. On many main lines there is, it is true, a very excellent and substantial track construction, second to none in this or any other country, but the aggregate length of such track is but a small proportion of the total mileage of railway track carrying heavy traffic. Within the past few years

there have been marked advances in track construction, notably in the use of heavier rails and of metal tie-plates, and in the introduction of improvements in frogs and switches, to insure a smaller expense for maintenance work, and a greater safety in the movement of trains. The improvement in track, however, has not kept pace with the growth of traffic and the increase of wheel loads and train loads, for the reason that the relation of the track and its maintenance to the safety and speed of trains, the train loads which can be hauled, and the economy of operation, are matters which (as already noted) are very generally overlooked by the financial and executive officers of railway companies. Practical experience, however, has conclusively shown the importance of good and smooth track in securing the maximum work by locomotive equipment, and the fact is coming to be recognized that the poorer the track the greater will be the expenses of maintenance, owing to the inability of the track to sustain the weight and shocks to which it is subjected. In fact, heavy expenditures for more powerful locomotives may in some cases be avoided by lighter expenditures to bring the track into such condition as to enable the equipment already on hand to handle the heavier traffic. The economy in maintenance expenses resulting from a substantial track construction increases in proportion to the traffic which is carried.

The heavy train loads and wheel loads of modern traffic have, as an average, been increased without relative increase in strength of track, and beyond the safe and economical capacity of any but the largest trunk line tracks, and it is an undoubted fact that on many roads the track is far below the requirements for safety and economy. The prevailing tendency is to increase the loads without consideration of the condition of the track, and on many roads the track is now far below the condition required for the safe and economic handling of the traffic. This means that the reduction in transportation expenses attained by increasing the train capacity is apt to be more than offset by the increased liability to accident and the increase in expenses for maintenance-of-way. The comparative lightness of the track of many American railways which use very heavy locomotives has frequently been commented upon, both in regard to the danger of derailment and to the increased cost of maintenance. The conditions of safety and maintenance, however, vary according to the nature of the road and the traffic, as a light track which would be safe on straight and level line, where the trains run easily, might be dangerous and expensive on a line with sharp curves and steep grades over which the engines work very heavily. On the other hand, a well-laid and maintained track may give better service than a relatively heavier track with low joints, worn ties and loose ballast.

In 1896 the author made a somewhat extended investigation as to existing standards of track details, and the results of this investigation were published in tabulated form with numerous comments and notes, in "Engineering News," New York, June 25, 1896. These tables are given as an appendix to this book. On the whole the showing made by this record appears to be satisfactory, but, unfortunately, the standards thus adopted represent, as a rule, not the actual track construction over the entire main line mileage of the several railways, but only that of a portion of the mileage, which portion is gradually increasing as renewals are carried on to meet the requirements of traffic. The other and older portion of the exist-

ing track is in very varying condition as to material and maintenance, and it must be admitted that light and worn rails, decayed and worn ties, a heterogeneous collection of frogs, a skimped amount of ballast and other defects are too often to be seen on important lines. This is due largely to financial conditions (the various good and bad reasons for which need not be considered here) and to the fact that the transportation or traffic departments have in general received much more and much closer attention than the roadway department.

For instance, the standards in weight of rails cannot be considered as more than meeting the demands for present requirements (with a very few exceptions), and it must be borne in mind that very few railways have their standard rail or standard track yet laid over more than a portion of their systems, while the lighter track has still to carry the increased traffic and loads, as already noted. It is this latter state of affairs which is responsible for so many of our railway accidents, and for the European prejudice against the American type of track.

The attention of managers and other higher officers should be called to the necessity for and advantages of the more rapid extension of improved standards for track construction. This subject has been treated of at some considerable length in the paper already referred to, on "The Relation of Track to Traffic on American and Foreign Railways," read by the author before the New York Railway Club in December, 1896, in which paper the general question was discussed and details were given of actual conditions fairly representative of existing practice.

It is encouraging to note that there is an increasing recognition of the fact that the management of the track department should be in the hands of engineers, and not merely in the hands of men who have shown themselves to be somewhat above the grade of the ordinary section foreman. This question, however, is fully discussed in the chapter on "Organization," but it may be well to point out here that there is still a strong and regrettable tendency on the part of financial and executive officers to ignore the special qualifications and responsibilities of the men they have entrusted with this department. The ignoring of recommendations and the cutting or disallowing of requisitions are specially faulty features of this practice, showing that these officers fail to put faith in the men who are in practical charge of the work and are consequently best fitted to know the requirements of the road. This action is partly due to the old system, under which the men in charge of the roadway had little recognition or authority, and partly to the fact that the higher officials are rarely educated in the principles of railway economics, and fail to understand that a present wholesale cutting of expenditures may mean a greatly disproportionate increase in the future, or that a present large expenditure may result in a material and far reaching economy in future expenses.

One thing which the engineer, roadmaster, superintendent and other technical officers have to fight against is the almost universal confusion of the meaning of the terms "cheapness" and "economy" by directors and non-technical officers. The general idea of such men is that if they buy certain supplies at a less price than estimated or recommended, or cut down some of the requisitions, they are practising a commendable economy, whereas it is very probable that they are wasting money on inferior articles and hastening the time when larger expenditures will be required. It is hard

to convince them that to pay $2 instead of $1.50 for a tool is a decided economy, or that if a requisition for ties is cut in half the distribution of the number where renewals are absolutely necessary will leave the track in little better physical condition than before. The technical officers should, however, have the courage of their convictions, based upon their personal knowledge, and should press their arguments home upon the directors, in an endeavor to convince them of the requirements of the case. In regard to requisitions, the responsible officer should not let one pass to his superior officer, or to the directors, etc., without being convinced that it is fair to the company and the road, and that he can sustain it if it is called in question.

He should at the same time be acquainted with the financial conditions of the company, and regulate his requisitions accordingly, so that these may not be radically cut down by the executive officers, when he might himself have distributed the cut more judiciously and to better advantage. In times of financial stringency the above noted tendency to cut down expenses on a large scale is particularly apparent, with the too frequent result that there is a deterioration in the physical condition of the property, which, besides the loss of reputation to the railway, will very generally render extra expenses necessary to bring the road back to reasonably proper condition. It should be recognized as an absolute fact that the poorer the track the greater will be the expenses for maintenance, owing to the inability of the track to sustain the weights and shocks to which it is subjected.

The object of the officer in charge of maintenance work should be to do the best work possible with the amounts appropriated for his use. If the company is rich he may turn his attention to important works or measures for the general improvement of the line, by which large expenditures will result in material economy in the future. If the company happens to be in a bankrupt condition or the road is in the hands of a receiver it should be his particular aim to get the best possible results with the least possible expenditure. Many railways, owing to poor financial conditions; have to get on in the track and other departments with very limited means, and the officers of the departments have to carry out their work in a sort of "hand-to-mouth" way that is by no means conducive to good or economical work, though it may be a matter of necessity. On the other hand, many roads apparently consider that with the road once built, expenditures for the track should cease, and while authorizing the expenditure of large sums for additional locomotives, over-decorated rolling stock, new works, and for passenger and freight competition expenses, in which economy might well be exercised, they are not willing to authorize additional expenditures in track work, even if the actual economy of such expenditures can be clearly shown. On many important roads, of course, things are very different, but under the above conditions of service, the engineers and superintendents of railways which cannot pay, and of those which can, but will not, pay for needed improvements, have to do the best they can with the material they have or can get, instead of with what they desire or need. The importance of the maintenance department is perhaps not understood so thoroughly by any one as by the men in charge of that department on a road where light track, heavy traffic and frequent admonition to keep expenses down, together with a constant sense of responsibility in case of accident, make railway work anything but an easy

problem. Men in such positions are often largely instrumental in the successful operation of the road, but their work and responsibility are usually but little known outside of their own offices.

A somewhat potent factor in the tendency to improve the track is the introduction of higher speeds, since such conditions cause the rails to cut out the ties and disturb the ballast so that the maintenance expenses increase to a marked extent where a material increase of speed is introduced for traffic over a somewhat light track. Where a substantial track construction is introduced, however, the subsequent cost of maintenance is likely to decrease in spite of the higher speeds.

Throughout this book there are given numerous rules and instructions as to methods of work, but it must be distinctly understood that no rule can be made universally applicable or should be blindly followed. Owing to local conditions of track, traffic, labor, etc., a method which may be the best practice in one case may be entirely unsuitable in another, so that each man must think for himself. He should not adopt a method simply because he finds it described in print, or assume that another method is wrong simply because it could not be applied to advantage on his own road. The engineer and roadmaster should comprehend the principles underlying their work, should be familiar with the general rules of practice, and should take into consideration the conditions under which the work is to be done. Then, upon this basis, they should adopt or devise such methods as will give the best and most economical results under the conditions prevailing on their own roads. It will be seen, therefore, that there is ample scope for a man to exert his skill and his executive ability in the conduct of the maintenance-of-way department.

In concluding this introductory chapter, the author gives the following summarized statistics, compiled from the report of the Interstate Commerce Commission for the year ending June 30, 1895:

AMERICAN RAILWAY STATISTICS, 1895.

Mileage.

Single track	180,658 miles.
Second track	10,640 "
Third track	975 "
Fourth track	733 "
Yard tracks and sidings	43,888 "
Total mileage operated	236,894 "

Employees.	No. per mile of line.	Total number.
General administration	18	32,525
Maintenance of way and structures	128	226,839
Maintenance of equipment	88	155,630
Conducting transportation	204	362,419
Unclassified	4	7,621
Total	442	785,034

General officers		34,352
Station agents, operators, and dispatchers		123,567
Enginemen, firemen and trainmen		157,731
Shopmen		151,965
Trackmen:		
Section foremen	29,809	
Sectionmen	155,146	
Switchmen, watchmen and flagmen	43,158	
		228,113
Miscellaneous		89,134
Total		785,034

Traffic.

Passengers carried	507,421,362	Passenger train mileage	317,565,615
Passengers carried one mile	12,188,446,271	Freight train mileage	449,291,238
Freight carried, tons	696,761,171	Total train mileage	766,856,853
Freight carried one mile	85,227,515,891		

Earnings and Expenses.

	Per mile of line.	Total.
Gross earnings from operation	$6,050	$1,075,371,462
Operating expenses	4,083	725,720,415
Net income	316	56,116,259
Percentage of operating expenses to gross earnings	...	67½%

Total Expenditures for Operation.

	Per cent. Op. exp.	Per cent. Total exp.	Total.
Maintenance of way and structures	19.84	13.28	$143,976,344
Maintenance of equipment	15.68	10.50	113,788,709
Conducting transportation	59.41	39.76	431,148,963
General expenses	4.95	3.31	35,907,017
Unclassified	0.12	0.08	899,382
Total operating expenses	100.00	.....	$725,720,415
Fixed charges	.....	33.07	358,551,762
Total expenditures	.....	100.00	$1,084,272,177

Expenses for Maintenance of Way and Structures.

	Per cent. Op. exp.	Per cent. Total maint. exp.	Total.
Repairs of roadway	10.32	51.63	$69,106,141
Rail renewals	1.51	7.56	10,124,633
Tie renewals	2.98	14.88	19,900,837
Repairs and renewals of:			
Bridges and culverts	2.29	11.44	15,312,954
Fences, road crossings, signs, cattleguards	0.52	2.62	3,508,856
Buildings and fixtures	1.66	8.31	11,127,444
Docks and wharves	0.24	1.19	1,590,635
Telegraph	0.14	0.68	906,348
Stationery and printing	0.03	0.16	222,495
Other expenses	0.31	1.53	2,053,498
Total	20.00	100.00	$133,853,841

CHAPTER 2.—ROADBED CROSS SECTIONS.

The general work of the construction of the railway does not come within the scope of this book, but it is assumed that the cuts and embankments have been made and completed to the level of the subgrade, and finished off to the required grades as laid down on the official profiles.

The width of roadbed (by which is meant the surface at subgrade) is from 26 to 32 ft. for double track and 14 to 18 ft. for single track on embankments; while in cuts it is from 28 to 33 ft. for double track and 18 to 22 ft. for single track. The minimum widths, however, should be 18 ft. in rock cuts, 20 ft. in earth cuts, and 16 ft. on embankments.

The surface at subgrade is almost invariably crowned at the middle to drain off water to the sides, the only exception of which the writer is aware being on the Eastern Railway of France, where the surface is made slightly concave, and tile drains are led from the bottom of the hollow to the face of the bank. The roadbed may be formed in different ways to throw off the water reaching it through the ballast: (1) It may have one or more planes from each side to the center; (2) it may have a curved surface, with a rise of 3 to 6 ins. for single track and 6 to 8 ins. for double track; or (3) it may have a flat center portion, with planes each side to the ditch. In regions of ordinary rainfall the best plan is to give a

slope, as it will throw off water better than a flat curve. The more solid and compact the surface of the roadbed is made before the ballast is applied, the better will be the drainage, and the latest specifications prepared by Mr. Katte, Chief Engineer of the New York Central Ry., require the subgrade to be as nearly homogeneous in composition and consistency as practicable, for a depth of 18 to 24 ins., solidified to uniform resistance by thorough ramming or rolling, and truly graded in regular drainage planes, having a rise of 6 ins. for a double-track roadbed 27 ft. wide on a bank. In some cases the roadbed is inclined on curves to give the proper superelevation to the track, but this practice is not general.

In some cases the slope of the roadbed is continued to meet the toe of the slope in cuts, but with earth or other poor ballast, and in country with ordinary rainfall, it is better to have a ditch reaching well below subgrade, so as to effectually drain the roadbed. The drainage of the track is effected by the ballast, the crowning of the subgrade, and by side ditches in cuts, which latter carry away the water from the ballast and roadbed, and this drainage is one of the most important items in maintaining a good track, its importance increasing as the quality or quantity of the ballast decreases, and increasing also in relation to the extent of rainfall. Climatic conditions are, of course, to be considered in designing the form of cross-section of roadbed, heavy ditching not being required in dry regions with light soil. On roads through country with a moderate rainfall, the ditches should, nevertheless, be of ample capacity to carry off the storm water in occasional heavy rains. The ditches should be parallel with the track, not made to wind around stumps or boulders, and must be graded so as to pass all water freely and to thoroughly drain the roadbed and keep both ballast and roadbed firm and dry. The width should increase towards the ends, and if the standard width does not give sufficient capacity, the ditch should be widened on the outer side.

The distance from the rail to the ditch varies according to the nature of the soil, and the bottom should be about 16 to 24 ins. below the crown of subgrade. An average arrangement in ordinary material is a distance of 7 ft. from the rail to the edge of a ditch 24 ins. wide on top, 18 ins. wide on the bottom, with the bottom 8 ins. below center of roadbed on single track, or 12 ins. on double track. In wet cuts the ditches may be lined with cement, or, in narrow cuts (especially where the earth slides or bulges) they may be lined with plank or old ties, with struts across the top. Subdrains of tile, brush, or wooden boxes may be laid as required. Where it is necessary to carry water from the ditch on one side to the ditch on the other side of the track, or from a center ditch to the side ditches (as on double track), box drains of wood are laid in the ballast. These box drains are usually 12 × 12 ins. inside, 12 to 16 ft. long, made of 2-in. plank, with the ends sloped to conform to the slope of the ballast, and having four or six flat strips, 2 × 6 × 16 ins. across the top. The ditches may be carried under road crossings by cast-iron pipe, clay sewer or culvert pipe, or wooden box drains. The first is preferable, as wood soon rots and lets dirt fall in to clog the drain, and clay pipe is liable to be broken, as there is generally very little cover over it. The size of the pipe varies according to the amount of water to be carried, but is generally 6 to 10 ins., while the box drain is usually about 8 × 10 ins., having plank sides and bottom, and a top of cross strips nailed close together

New York Central Ry. (Fig. 1).—The roadbed is 26 ft. wide. Upon this is a 6-in. course, 25 ft. wide, of rough quarry spawls, 4 to 6 ins. in size,

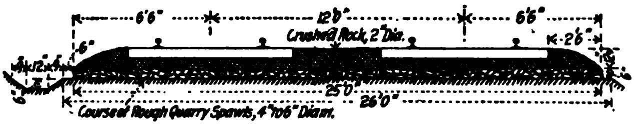


Fig. 1.—New York Central & Hudson River Ry.

closely laid, like the foundation of a telford road; on this again is a 12-in. course of 2-in. broken stone, filled in to the tops of the ties.

Pennsylvania Ry. (Fig. 2).—The roadbed is 19 ft. 2 ins. wide for single track, 31 ft. 4 ins. for double track, 43 ft. 6 ins. for three, and 55 ft. 8 ins. for four tracks. It has a slope of 1 in. in 4 ft. from the centre to the edge of the ballast, and then a berme of 6 to 1 slope, 3 ft. 6 ins. wide, to the edge of the ditch or bank. The ballast is 12 ft. 2 ins. wide for single track and 8 ins. deep under the ties, but is not shouldered out beyond the ends

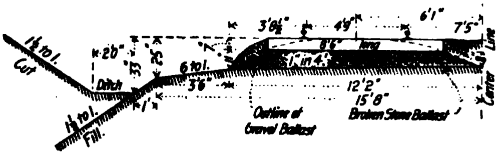


Fig. 2.—Pennsylvania Ry.

of the ties. With more than one track the stone ballast is filled in for the full width, but gravel is sloped down between the tracks. In soft places cinder ballast is used until the roadbed has settled and become consolidated. The standard section, as shown, has a well-formed ditch, but for single track with light traffic there is no ditch. The quantity of ballast in cubic yards per mile is as follows:

	One track.	Two tracks.	Three tracks.	Four tracks.
Stone	2,315	5,300	8,500	12,260
Gravel	1,900	4,075	6,950	10,185

New York, New Haven & Hartford Ry. (Fig. 3).—This has a flat roadbed 30 ft. wide for double track, with no ditch. Stone ballast is level with the tops of the ties and shouldered out 12 ins. beyond their ends, while

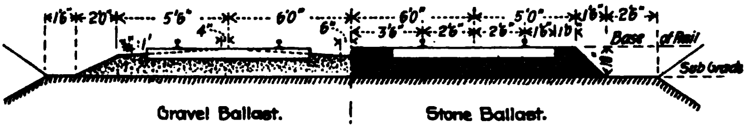


Fig. 3.—New York, New Haven & Hartford Ry.

gravel ballast is sloped to 4 ins. below the tops of ties at their ends, forming a ditch between tracks on double track, long box drains being placed at intervals to carry the water to the sides.

Lake Shore & Michigan Southern Ry. (Fig. 4).—The roadbed is 32 ft. wide for double track, or 47 ft. 6 ins. over the ditches in cuts. The ballast is of gravel, sloped down between the tracks, and in cuts it is carried

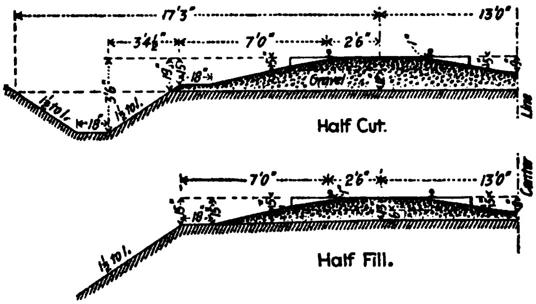


Fig. 4.—Lake Shore & Michigan Southern Ry.

out to the edge of the ditch, which does not seem to be advisable. The ballast is 12 ins. deep under the ties in cuts, and 6 ins. on fills. The quantity of gravel in cubic yards per mile is as follows:

In cuts.		On fills.	
Single track.	Double track.	Single track.	Double track.
3,749	6,917	2,165	4,171

Baltimore & Ohio Ry. (Fig. 5).—The single-track roadbed is 19 ft. 1½ ins. and 17 ft. 1½ ins. wide for cuts and fills, respectively, and the double-track roadbed is 31 ft. 1¾ ins. and 29 ft. 1¾ ins. wide, no ditches being used. Stone and cinder ballast (the latter for side tracks) are shouldered out 3 ins. beyond the

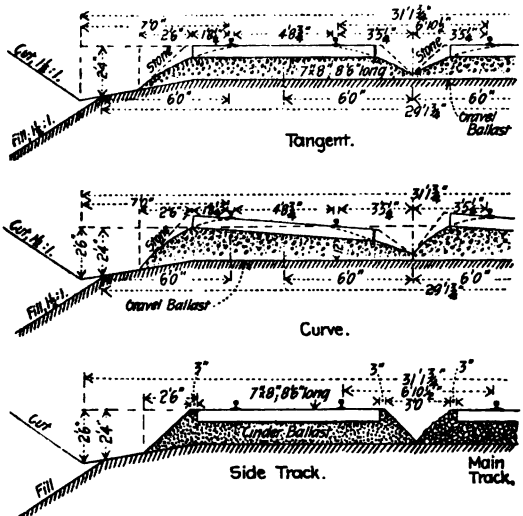


Fig. 5.—Baltimore & Ohio Ry.

ends of the ties, while gravel is given a rounded surface, touching the bottoms of the ends of the ties. The depth of ballast is 12 ins. under the

ties, and on curves each track has its rails on a separate plane, and the ballast is 12 ins. deep under the lower rail. Stone and gravel ballast are sloped down between the tracks.

Chicago, Burlington & Quincy Ry. (Fig. 6).—The single-track roadbed is 16 ft. wide, with a rise of 4 ins. at the middle. Burnt clay ballast is

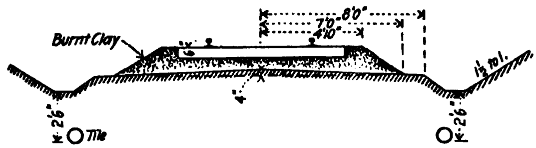


Fig. 6.—Chicago, Burlington & Quincy Ry.

laid 8 ins. deep under the ends of the ties, and shouldered out about 10 ins. beyond their ends. The cut shows tile subdrains under the ditches.

Illinois Central Ry. (Fig. 7).—In using earth ballast it is filled in 4 ins. over the middle of the ties, flat on top, and sloped down under the rails to the bottom of the tie at the ends, extending thence 5 ft. to toe of slope,

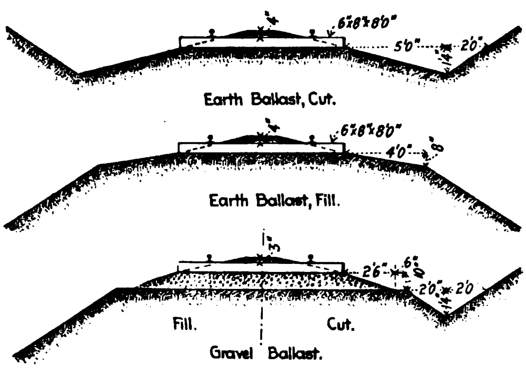


Fig. 7.—Illinois Central Ry.

or 4 ft. to edge of bank. With fine gravel the section is similar, but filled in only 3 ins. over the ties, 10 ins. deep under the ties, sloped 1½ to 1 and leaving 6 ins. between edge of ballast and edge of roadbed.

Southern Pacific Ry. (Fig. 8).—The single-track roadbed is 18 ft. wide in cuts, while in fills it is 15 ft., 14 ft. 6 ins. and 14 ft. for stone, gravel and earth ballast, respectively. There is a depth of 8 ins. of ballast under

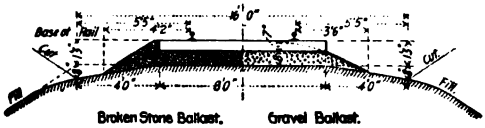


Fig. 8.—Southern Pacific Ry.

the middle of the ties. Stone ballast is shouldered out 6 ins. beyond ends of ties, and sloped 1 to 1. Gravel is filled in about 2 ins. over middle of ties, and sloped nearly to the bot-

tom at the ends of ties. Earth is filled in over the ties and sloped to the bottom at the ends, and thence sloped 12 to 1 to the top of the bank. At stations fine sand or engine cinders are filled in over the ties between rails and tracks. The edges of banks are rounded off.

Atchison, Topeka & Santa Fe Ry. (Fig. 9).—The single-track roadbed is 22 ft. wide in cuts and 18 ft. 8 ins. wide on banks. The ballast is 10 ins. deep under the ties, and gravel and stone are level with the tops of

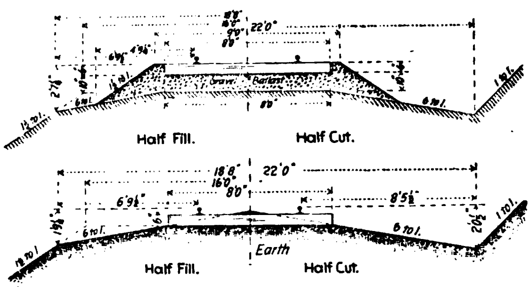


Fig. 9.—Atchison, Topeka & Santa Fe Ry.

the ties and shouldered out 6 ins. beyond their ends, the stone being sloped 1 to 1, and gravel 1½ to 1. Burnt clay and cinder ballast are formed the same as gravel. Earth is filled in over the middle of ties and sloped to bottom of end of tie, and thence 6 to 1 to edge of cut or bank.

Minneapolis, St. Paul & Sault Ste. Marie Ry. (Fig. 10).—The single-track roadbed is 12 ft. wide, crowned 0.2 ft., and having 6 ins. of ballast under the centre of the ties. The width is 20 ft. c. to c. of the ditches, which are 2 ft. deep. Gravel is filled in 1 in. over the ties and sloped to 3 ins. below top of ties at ends, shouldered out 12 ins. beyond the ends, leaving 12 ins. between ballast and edge of ditch. Sand ballast is filled in level with tops

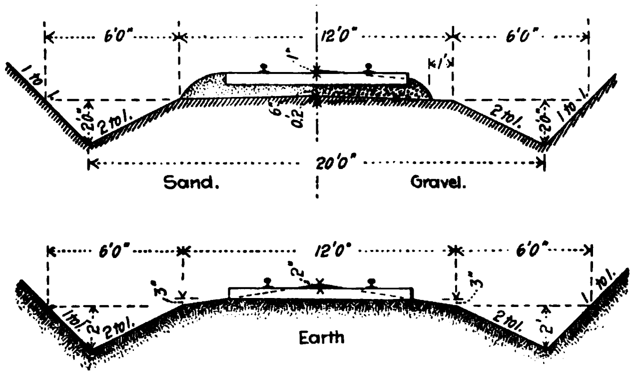


Fig. 10.—Minneapolis, St. Paul & Sault Ste. Marie Ry.

of ties, shouldered out 12 ins., and rounded to the edge of the ditch, an arrangement which seems likely to cause the sand to flow into the ditch. Earth or loam is filled in 2 ins. over the ties at the middle, and sloped under the rail to the bottom of end of tie, and thence to edge of ditch. In places

where it was necessary to excavate to a depth of 1 to 3 ft. in sandy ground, the roadway was made 28 ft. wide at subgrade, with ditches 8 ft. wide and 2½ ft. deep.

The Southern Ry. has a standard single-track roadbed 18 ft. wide between toes of slopes of cuts; the surface being curved, with a rise of 8 ins. Stone ballast is laid to a depth of 8 ins. under the ties. The ballast is level with the tops of the ties, and rounded off from their ends to a bottom width of 16 ft. The Chicago & Alton Ry. slopes its roadbed with a rise of 3 ins. for single track and 5 ins. for double track, putting 10 ins. of stone or gravel ballast under the middle of the ties and shouldering it out 12 ins. beyond their ends, while between the tracks it is level with their ends. The Richmond, Fredericksburg & Potomac Ry. has a single-track roadbed about 16 ft. wide, with gravel ballast sloped from edge of ditch to bottom of tie, leaving the ballast flat for 3 ft. 2 ins. between the rails. The ditch is formed by a slope from the roadbed to toe of cut, the bottom being 30 ins. below top of tie and 20 ins. from edge of roadbed. The gravel ballast is 10 ins. deep under the ties.

The Cleveland, Cincinnati, Chicago & St. Louis Ry. has a somewhat unusual cross section of track with stone and gravel ballast. Stone ballast, as a rule, is filled in level with the tops of the ties for the entire length of the ties, and then either sloped down from the ends or shouldered out 3 to 12 ins. beyond the ends. On this road, however, it is sloped, like gravel, from inside the rails to the bottom of the tie at the ends, and thence to the roadbed, the slope being much flatter than that usually adopted for stone. The gravel ballast is sloped in the same way, leaving the top flat for a width of over 4 ft., though it is more common practice to commence the slope near the middle of the track. On double track, the gravel is sloped down between the tracks, leaving about 3 ins. of ballast at the lowest point. The Lehigh Valley Ry., on its new Buffalo line, has a double-track roadbed 28 ft. wide in cuts and on banks, with a V-shaped ditch 8 ins. deep, making the width 32 ft. over ditches in cuts. The stone or slag ballast is 2 ft. deep, level with tops of ties and rounded off from their ends.

Tunnels.—In rock tunnels the floor is generally flat, sometimes with a trench drain down the middle, covered by flat stones to keep out the ballast; or else a pipe drain is laid in the trench and the ballast filled in

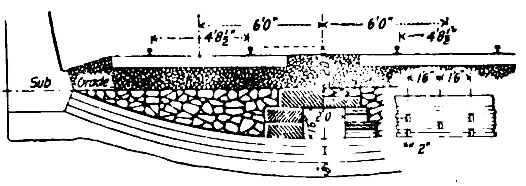


Fig. 11.—Baltimore Belt Line Tunnel; B. & O. Ry.

around it. With this arrangement the ballast is usually filled in level with the ties for the full width of the tunnel, but if there is no drain the ballast may be sloped in the usual way to form side and center ditches. If the tunnel has an invert there is usually an arched or box drain of brick or dry stone masonry built upon it and covered by the ballast, though sometimes a pipe drain is laid in the ballast. The designs for brick and

stone drains in the Howard St. tunnel of the Baltimore Belt Ry. are shown in Fig. 11. In single-track tunnels the floor may be flat or have center or side drains. Figs. 12 and 13 show the arrangement of floor, ballast and

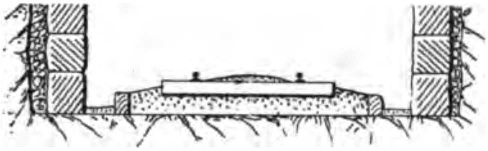


Fig. 12.—Boulder Tunnel; Montana Central Ry.

drains adopted for the Boulder tunnel of the Montana Central Ry. and in the tunnels of the Everett & Monte Cristo Ry. Fig. 14 shows the arrangement of open floor and drain in the St. Clair circular iron-lined tunnel of the Grand Trunk Ry.

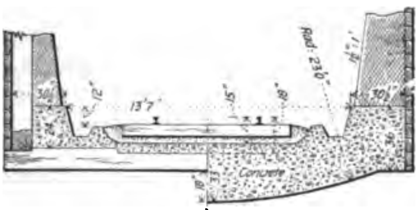


Fig. 13.—Tunnels; Everett & Monte Cristo Ry.

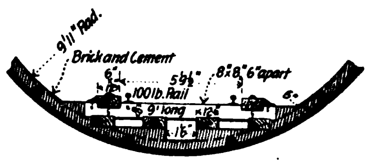


Fig. 14.—St. Clair Tunnel; Grand Trunk Ry.

Viaducts.—Masonry viaducts usually have the floor built to form drainage planes and ditches, or gutters, the drains being carried across the structure or leading to weeper holes or pipes forming outlets at the haunches of the arches, either at the spandrel walls or in the intrados of the arch.

Yards.—In yards there should be an ample depth of good ballast, with drains or water boxes leading to main drains, and these drains should be carefully cleaned and put in order just before winter. A wet, muddy yard is a source of inconvenience and discomfort to the yardmen, and is an evidence of a neglect of proper maintenance.

CHAPTER 3.—BALLAST.

The ballast is a most important item in securing a good track and economy in maintenance and operation. The material should be carefully selected, as it may have a decided effect on locomotive and car maintenance, as well as on the traffic. A dusty ballast will cause greatly increased wear of the journals and motion, and on roads with extensive passenger traffic it is as important to avoid dust and dirt by the use of clean ballast as it is to avoid smoke and dirt by the use of hard coal for fuel for the locomotives. The purpose of the ballast is to distribute the load over the roadbed, to form a support for the ties, to provide efficient drainage around and under the ties, and to allow of surfacing and raising track without disturbing the roadbed. It should not be laid until the roadbed is completed to grade and properly compacted, and should not be used for raising banks to grade. If track is to be ballasted and raised to give less than the standard depth of ballast, the roadbed should be cut down the required amount; and if the raise will give much more than the standard depth the roadbed should be filled in before the ballast is laid, so as not to use the ballast for mere filling. On the other hand the quantity of ballast should be liberal. About 18 ins. below the tie is an excellent depth for ballast, but is not often found; 12 ins. should be a minimum depth under the ties for heavy traffic, and the depth should be kept as uniform as possible. Where an old roadbed has been frequently reballasted the ballast will be found to extend to a considerable depth, gradually becoming poorer from being worked into the soil, but this makes a good foundation for the ballast proper.

The best ballast is that which will best form a durable support to the ties, retain its solidity and position under the effects of traffic, give good drainage, be free from dust, and make an easy riding track. Where water is retained under and around the ties the ballast will soon deteriorate and be churned up, and bad track will result. A layer of coarse slag, broken stone, or large cinders along the tracks will have a tendency to check the too-prevalent custom of persons walking on the track. The ends of ties (except in easy draining material, such as slag or broken stone) should be left entirely free, in order to allow water to escape quickly from under them, as in soft or earthy material the ties will gradually work down and, unless the ends are kept free, churning will result. In gravel, however, some roads fill the ballast a little above the bottom at the ends.

The materials most generally used are broken stone, furnace slag, burnt clay, gravel, sand, cinders and earth. The first two drain readily, but gravel, burnt clay, earth, etc., will retain water more or less (according to quality), and will heave in frosty weather. With earth or mud ballast good drainage is absolutely essential to enable the track to be kept in safe and fairly good condition, as water-soaked earth becomes pasty and unmanageable, impossible to tamp and put in condition. A good depth of ballast will greatly facilitate maintenance by keeping the beds of the ties well drained, and it is a mistaken policy to economize too much in ballast. In fact, it is an excellent plan for roads to own gravel pits and keep working them. The cross-sections of the bed of ballast varies

with the material, the climate and the ideas of the engineers, as already shown by Figs. 1 to 10.

Broken Stone.—This is in general the best material for ballast, as it meets the requirements given above, does not freeze solid nor heave in cold weather, and can be worked in wet and dry weather alike. Almost any hard and tough stone may be used, providing it breaks into cube-shaped pieces and not into thin flat pieces; but granite, trap and limestone are most used. The stone should be broken to a uniform size of 1½, or 2 ins., and on some roads a bottom course, 6 to 10 ins. deep, of large rough stones, is laid as a foundation, as in telford paving, and covered with the smaller stone. Very coarse stone leaves too many voids, reducing the stability, and it would be much better to have these filled with finer material. In general, the broken stone is bought from contractors, but where the road has its own crushing plant the crusher should, if possible, be placed above the track, and even with or below the source of supply (quarry or excavation), so that the rock can be dropped into the machine and the broken stone delivered into the cars by chutes. In some cases the stone is broken by hand on the track, the track being raised to surface by stones or blocking under the rails, and the large stone delivered into the middle, where it is broken up by ballast hammers. A rock crusher mounted on a flat car is sometimes used, being hauled from place to place as required. The Austin machine consists of a crusher and engine mounted on a frame and wheels, and fitted to propel itself along the track. It has one pair of driving wheels, and when the site of operation is reached the wheels are raised and act as flywheels for the crusher, while a cogwheel arrangement then moves the machine slowly along the track while crushing.

In cross-section the ballast is usually level with the tops of the ties, and extended or "shouldered out" beyond their ends, as the material drains readily and so will not hold water under the ties, while the shoulder helps to hold the track in line. In some cases the ballast is rounded off from the ends of the ties, as shown in Fig. 2, but it is better, and looks neater, to shoulder it out, especially as there is more tendency to lateral motion of track on stone than on other kinds of ballast, owing to the comparatively small number of points upon which the ties rest. The slopes are sometimes hand faced for appearance. On double track the stone ballast is generally continued level across the whole width, but is sometimes sloped to form a center drain, while on the Cleveland, Cincinnati, Chicago & St. Louis Ry. the ballast has a curved top surface, as already noted. Large stones may be laid between the tracks (and covered with ballast) to form a drain, and at the bank sills of trestles, etc., but must never be placed under the ties. In some cases a layer of gravel is laid upon a bottom layer of broken stone, but this is not general, and it is not to be recommended, though claimed to combine the good drainage of stone with economy in material, as gravel is in general cheaper and more easily procured. The 2½-in. stone is sometimes covered with a top dressing of 1-in. stone, and the Pennsylvania Ry. in some places lays small broken stone over the regular ballast and covering the ties, the purpose being to deaden the sound in the cars. The new steel ties for the New York Central Ry., Fig. 22, will be entirely covered with ballast, except over the rail fastenings. This practice is not good with wooden ties as a rule, as it leads to rotting by keeping the ties damp and prevents inspection,

but in very hot, dry regions it may be permissible in order to protect the ties from the sun. Stone ballast should be handled with forks and not with shovels, so as to avoid putting dirt into the track, as the dirt hinders the drainage and affords a chance for weeds to grow. From a maintenance point of view it may be noted that stone ballast on a poor road involves greater expense for renewal and maintenance (perhaps at a time when little money is available) than where gravel is used.

Slag.—Furnace slag or cinder is extensively used on roads in the vicinity of blast furnaces and iron works. It is about as durable as broken stone, and in other ways almost as good, though it is sometimes said that ties decay in it more rapidly than in stone ballast. If properly drained, however, the difference is but small. It is considered that it should be as free from lime as possible, but a reported corrosion of rails on slag ballast does not seem to be substantiated. Mr. Mordecai, Assistant Chief Engineer of the Erie Ry., states that furnace companies are generally glad to supply the material free on cars at the furnaces in order to get rid of it. It does not require a great deal of labor to break it up, and costs about as much to put under the track as stone, possibly a little less. It should be broken to a 2-in. or 2½-in. ring, and, like stone, it should be handled by forks so as to be free from dust and dirt. There should be at least 10 ins. of slag under the ties. The tamping is done in the same way as with stone, though Mr. Mordecai thinks that slag requires a little more tamping in the middle of the tie, so as to keep the track in good condition for easy riding. It gives excellent results, keeps the track in good line and surface, and does not heave as much as gravel. On the Chesapeake & Ohio Ry. it has been used for some years, the average depth under the ties being 12 ins., and Mr. Frazier, Chief Engineer, states that it is very satisfactory and economical. The bulk of this slag is as small as ordinary gravel, and is loaded with a steam shovel. The engineer has been able to get it in this condition by arranging with the furnaces to pour the hot slag from the pots down an incline 30 to 40 ft., when the slag spreads out and cools very rapidly. This gives it the appearance of broken china, instead of the porous, sponge-like appearance of the large lumps of slag handled in the ordinary way. On the Lehigh Valley Ry. a 12-in. bed of slag is sometimes put under the ties, and then covered with anthracite ashes filled in between the ties. The cross-section is usually formed similar to that for broken stone, and an important feature of slag ballast is that owing to the sharpness of its edges it checks people from walking on the track. It is extensively used in England, where it is run from the furnace onto a traveling belt and suddenly cooled by water, which hardens it and breaks it up at the same time. In view of its low cost and its excellence as ballast, it might well be adopted by many roads which now use an inferior gravel on their main tracks. If the traffic is heavy, the improved condition of track and the reduced cost of maintenance would probably warrant the expense for transportation of slag ballast from the furnaces.

Burnt Clay.—This has been used in England and other foreign countries for over 20 years, and its use is extending in this country, mainly in the West. The most suitable material is brick clay (or almost any clay that has not too much sand), and gumbo or clayey earth, and experiments have been made with the "black wax" earth of Texas. The site for burning is cleared of top soil, and a row of old ties, cordwood, etc., about 3 ft. high,

is laid the length of the kiln, 500 to 4,000 ft. This is covered with a few inches of slack coal, or slack and lump mixed, upon which is thrown a layer of clay 9 to 12 ins. thick. The wood is then lighted at intervals, the openings being closed when the fire is started. As the burning proceeds another layer of coal is placed, and another layer of 6 to 9 ins. of clay, and these layers are repeated from time to time until the finished heap is about 20 ft. wide and 10 ft. high. One ton of slack coal will burn 4 to 5 cu. yds. of clay, and the cost varies from 35 to 85 cts. per cu. yd. loaded on the cars. About 1,000 cu. yds. per day can be burned in a kiln 4,000 ft. long, about 50 men being employed. The work is usually done by contract, the company furnishing the land, sidetrack and coal. Partial estimates are given on kiln measurements, and the final estimate is made from car measurements when loaded out, so that worthless material is not paid for. The ballast is light (40 to 50 lbs. per cu. ft.), easily handled, gives good drainage, is free from weeds, is not dusty, and is in general satisfactory, requiring renewal in six to eight years. It is said to crush rather easily under the ties and to necessitate shovel tamping, but the writer does not consider that shovel tamping is necessary with any ballast, under ordinary conditions. The cross-section is formed similar to that for stone ballast, and there should be at least 12 ins. under the ties, as this ballast must be used liberally to give good results. Further particulars of the manufacture and use of this material are given in the writer's paper on "Improvements in Railway Track" (Transactions, American Society of Civil Engineers, March, 1890), and in "Engineering News," New York, Nov. 16, 1893. The cost per cubic yard of ballast in the track is about $1.05, distributed as follows, the price for the first item being variable:

Contract price for burning	38 cts.
Average cost of coal	21 "
Loading on cars	8 "
Distributing	9 "
Putting under track	22 "
Interest and depreciation	4 "
Land	1 "
Miscellaneous expenses	2 "
Total cost per cu. yd.	$1.05

The burnt clay ballast used on the St. Louis, Keokuk & Northwestern Ry. is a black clayey soil or gumbo, and the railway company contracted for it burned in the pit, the company laying the necessary tracks, furnishing the old ties and slack coal for burning, and loading and hauling the burned ballast. The cost on cars at the pit was estimated at 65 to 70 cts. per cu. yd., which is higher than usually estimated, but a number of small items were included which are sometimes overlooked. The burnt "black wax" soil ballast on the Texas Midland Ry. is said to cost $1 per cu. yd. in the track, and to have the advantage of being absorbent, so that in ordinary rainfalls most of the water is taken up by the ballast (which does not soften) and does not go through to the roadbed.

Gravel.—This material is more used than any other in this country, and is of very varying quality. It may be sandy and dusty, or loamy (when weeds will grow, drainage will be affected and the track will heave), or else full of large stones, which make an irregular and rough riding track. The best gravel should be clean and coarse, and as far as possible of uniform size and quality. It does not give as good drainage as stone, but a fairly coarse and clean gravel will be generally satisfactory. It is good econ-

omy to use plenty of gravel, giving at least 8 ins. (or better 10 ins.) under the ties, as it will enable a fairly good track to be maintained nearly all the year through without excessive work. It can be tamped by picks or bars, the latter being generally preferred, and is easily taken care of. In Europe the gravel is sometimes thoroughly washed by machinery to free it entirely from earth and sand.

There are varying opinions as to the cross-section, depending upon the quality of the material and the climatic conditions. Thus with good, clean, coarse gravel, or in warm, dry regions, it is better to make the section as with broken stone, bringing the ballast level with the tops of the ties and shouldering it out 6 to 12 ins. from their ends. With inferior, fine or loamy gravel (and this is the quality most generally met with), or where water and frost have to be considered, it is better to slope the ballast from the middle of the tie to the ends, to allow the water to drain off and not be held back by the rails, the ballast being 1 in. clear below the rail base. The slope may be made continuous with that of the roadbed to the ditch, and may be to the bottom of the end of the tie, or a little higher, so as to leave part of the end embedded, but this latter arrangement is likely to retain water along the ends of the ties. In some cases the ballast is flat on top for about 3 ft. and then slopes down under the rails to the bottom of the ties. Fine gravel is sometimes filled in 2 or 3 ins. above the ties at the middle, but in wet country this keeps the ties damp and leads to rotting, though in dry country it may protect them from the sun and from hot engine cinders. The Houston & Texas Central Ry. fills in the gravel between the rails to the level of the under side of the rail heads. On double track the ballast is usually sloped towards the middle of the roadbed to form a central drain, which should be at least 6 ins. below the ties, and is sometimes carried down to the surface of the roadbed. Cross box drains in the ballast carry the water to the side ditches. At stations on the Southern Pacific Ry. the ties rest on 8 ins. of ballast, and cinders are filled in nearly to the underside of the rail heads between the rails and between the main and side tracks.

Cinders.—Engine cinders make a cheap and serviceable ballast, which will last for some time under light traffic. Being porous it drains well and does not hold moisture. It is easily handled by the shovel, does not heave much with the action of frost, and prevents weeds from growing. The principal objection is that it makes a very dusty track until after some length of service, when the rain and traffic compact the material very thoroughly. It is very generally used for sidetracks and yards. With a wet roadbed. and with earth or mud ballast in the spring, or in wet weather when the earth is too soft to fulfill its purpose, a good layer of cinders will much facilitate maintenance, and in very bad cases the mud holes or wet spots may be dug out and filled with cinders. The cinders should not be laid on earth ballast, however, when the frost is coming out of the ground, or this action will be checked, and it will be late in the season before it is thoroughly out. In cross-section the ballast is sometimes formed the same as for broken stone, and on sidetracks it may either be sloped down to form a drain between that and the main track, as on the Baltimore & Ohio Ry., or be filled in level, as on the Erie Ry. The cinders are sometimes applied upon a bed of stone or slag ballast upon which the ties rest.

Sand.—This makes a fairly good ballast under light traffic, but unless

it is very coarse it requires constant attention and renewal, involving considerable maintenance work, as it flows from under the ties with the pumping motion of the ties, and is gradually drifted away by the wind and washed away by the rain. It is generally shaped the same as gravel, but if well shouldered out from the ends of the ties and level with them, as on the Minneapolis, St. Paul & Sault Ste. Marie Ry. (shaped the same as broken stone ballast), Fig. 10, it will hold the track better and there will be much less flowing from the ties. Owing to its instability it does not keep track well in alinement. It is convenient to handle, and drains fairly well, but it heaves in winter, makes a dusty track and is very hard on the journals and machinery. In India sand ballast is often covered with a layer of broken stone or broken brick to prevent strong winds from blowing it away. Special grasses or bushes may also be used as wind breaks in sandy districts.

Earth.—Dirt, earth and mud are terms used for ballast composed of the natural soil along the line, and this is the cheapest material to use, but often the most troublesome to maintain. It is of variable quality, from sandy to clayey. Unless very sandy it cakes in hot weather, and if any work is done on it, then it becomes intolerably dusty. In the winter it heaves badly by frost. In rainy weather it washes out, and in continued wet seasons or in the spring, when the frost is just out of the ground, it may become so soft as to make it impossible to keep track in safe condition, the ties churning the saturated roadbed into mud. In such a case good results may be obtained by digging out the mud and applying cinders liberally, or sometimes sods, brush, or coarse grass are placed under the ties. To keep the track in anything like good condition, thorough drainage is necessary, and on some lines in the Argentine Republic, where the black loam is used for ballast, the surface is very carefully formed and sloped to drain rapidly to transverse and longitudinal channels, while in some cases grass is allowed to grow upon the roadbed. The ballast is usually filled in 1 to 4 ins. over the ties at the middle, and curved or sloped sharply (leaving about 1 to 1½ ins. under the rail) to the bottom of the tie at the ends, and the slope is carried out on the same or a steeper slope to the ditch or edge of bank. The flat slope will carry the water off more quickly than the curved cross-section. If the earth is at all above the bottom of the tie at the end, it is liable to form a pocket to hold water. The roadbed should be thoroughly consolidated, so as to keep it separate from the earth ballast as far as possible, and thus assist drainage.

CHAPTER 4.—TIES AND TIE-PLATES.

The importance of the question of ties and their source of supply is shown by the fact that with an average of 2,500 ties per mile, the 235,000 miles of track of the United States (including second, third, fourth and side tracks) represent 587,000,000 ties. The annual consumption is about 76,000,000 ties for renewals and 14,000,000 for new construction, or a total of about 90,000,000 ties, which is equivalent to 450,000,000 cu. ft. of forest-grown material, or 500,000,000 cu. ft. if we include the consumption for bridges and trestles. This requires the annual culling of the best timber from probably more than 1,000,000 acres,

and the annual product of at least 50,000,000 acres in good condition, or more than 10% of the present forest area of the United States. These figures are taken from Bulletin No. 9 (1894) of the Forestry Division, U. S. Department of Agriculture.

Wooden ties will undoubtedly continue to be generally used in this country for many years, but great economy in their consumption can be effected, to the benefit of the railways and of the country in general. The use of preservative processes to prevent decay, and of protective metal tie-plates to prevent the wear and disintegration (and consequent local rot) under the rails, results in an increased life of ties and reduced expense for renewals, and makes a better track, which requires less work for maintenance. The adoption of such preservative and protective methods is, therefore, strongly advocated, since ties of the cheaper and (if untreated) inferior timbers, may thus be made even superior to ordinary ties of the better species of timbers, and still cost about the same as, or even less than, the latter. The use of a more efficient rail fastening than the common spike will increase the average life of ties. Greater care in inspections for renewals, so as to ensure that the ties are allowed to give their full effective life, will also result in better track being maintained at reduced cost.

There is no economy in the use of ties of poor quality, or in buying a lot of ties simply because they are cheap. The cost of placing is the same, they give worse service, they require more frequent attention, and the maintenance and renewal therefore cost more, while the frequent disturbance of ballast and track make it almost impossible to maintain a good riding track. An important economy resulting from the use of good ties and of methods of increasing their life, is the lessened disturbance of the track, thus permitting the ties to find a solid bearing in the ballast and to remain upon it. In this lies one of the reasons for economy in maintenance with metal ties, which, when once seated, may be left for several months with very little work upon the ballast.

The principal woods used for ties, and the proportions in which they are used, are about as follows: Oak, 60% of all ties used; pine, 20%; cedar, 6%; chestnut, 5%; hemlock and tamarack, 3%; redwood, 3%; cypress, 2%; various woods, 1%. The geographical distribution cannot be closely defined, but may be stated generally as follows:

New England States.—Chestnut, cedar, white and red oak, hemlock, tamarack, yellow pine, spruce.

Middle Atlantic States.—White oak, cedar, yellow pine, chestnut, tamarack, hemlock, cypress, cherry, locust.

South Atlantic States.—Pine, cypress, oak.

Northern Central States.—Oak, cedar, hemlock, tamarack, ash, locust.

Gulf and Mississippi Valley States.—Oak, pine, cypress.

Northwestern States.—Oak, elm, pine, tamarack, spruce.

Southwestern and Pacific States.—Oak, cedar, pine, spruce, cypress, redwood.

It must be remembered that the life of ties varies considerably in different sections of the country and on different roads, owing to the varying qualities of timbers of the same species, and to the varying conditions of climate, weather, roadbed and traffic. Farther, where ties are obtained continually from one section of the country, it is observed that the life of the ties is gradually becoming less as the timber resources become picked over. More specific information as to the distribution and life of ties is

given in Table No. 1, showing the life of different woods on different railways. This table is taken from the author's report on "Metal Ties, and Preservative Processes and Metal Tie-Plates for Wooden Ties" (Bulletin No. 9, Forestry Division, U. S. Department of Agriculture; Washington, D. C., 1894):

TABLE NO. 1.—LIFE OF WOODEN RAILWAY TIES.

Railways.	Ties.	Ave. life, years.
Delaware & Hudson	White oak..	7 to 12
Do.	Chestnut....	5 to 10
Lake Shore & Michigan Southern.	White oak...	6
Lehigh Valley	White & rock oak.	8
Do.	Cypress.....	8
Do.	Chestnut....	8
Do.	Yellow pine.	7
Pennsylvania	White oak..	5 to 6
Do.	Rock oak....	5 to 6
Allegheny Valley	White oak..	9
Central of N. J.	Oak	8
Do.	Yellow pine..	8
Do.	Chestnut....	6
Baltimore & Ohio	Oak	8
Boston & Maine	Chestnut, cedar & hemlock.	5 to 7
Michigan Central	Oak	6 to 9
Do.	Cedar	6 to 9
Do.	Tamarack ..	4
Do.	Hemlock ...	4
Cleveland, Cincinnati, Chicago & St. Louis.	White, burr & chestnut oak;; wild chr'y, hon'y locust and blk. walnut.	Ab't 9
Alabama Midland	Yellow pine.	5 to 6
Nashville, Chattanooga & St. Louis	White or post oak.	6
Missouri, Kansas & Texas	White, post & burr oak; cherry and sassafras.	6 to 8
Burlington, Cedar Rapids & Northern.	White oak & cedar.	8¾
Flint & Pere Marquette.	Hemlock ...	5
Do.	White oak ..	8 to 9
Do.	Cedar	8 to 10
Chicago & Alton	Oak	8
Do.	Cedar	6
Chic. & Northwest'n.	White oak..	6 to 8
Do.	Cedar	10 to 12
Do.	Hemlock ...	5 to 7
Minneapolis, St. Paul & Sault Ste. Marie	Cedar & oak.	8 to 10
Do.	Hemlock and tamarack.	6 to 7
	Red spruce..	6
Denver & R. Grande.	Yellow pine.	5
Do.	Oak	6 to 10
Union Pacific	Pine	5 to 8
Do.	Red spruce .	8
Do.	White cedar.	8 to 9
Do.	Pine (burnetized).	7 to 9
Do.		
Do.	Oregon fir & pine.	4 to 7
Do.	Tamarack ..	5
Louisville & Nashville.	White & post oak.	7 to 8
Chicago, Burlington & Quincy.	Oak, cedar..	8
Do.	Yellow pine.	5 to 7

White oak is the best wood for ties, both for wear and durability combined, being very hard and slow to rot, and generally failing by decay rather than by wear. Its average life is about 8 years under heavy traffic, though it sometimes lasts 12 years. Burr or rock oak, post oak and chestnut oak are next in value. Chestnut oak cut in May or June for tanbark must be seasoned differently from that cut in the winter. These oaks last about 6 to 10 years, and are largely used for switch timbers. Pin oak is a medium quality. Black, red and yellow oak (which names are often used indiscriminately) are decidedly inferior species, lasting only about 4 or 5 years as a rule, and as they decay from the interior, they are somewhat unreliable. Oak ties usually decay first in the part bedded in the ballast.

Chestnut is equal to oak in point of durability, and from its resistance to decay is generally preferred to the latter for fence posts. White chestnut may last 10 years on tangents and under light traffic, but with heavy traffic it cuts under the rails and on curves it does not hold the spikes well. The ties have a tendency to split, and they usually decay first in the part above the ballast.

Pine is very largely used in its numerous varieties, of which yellow and white pine are the best, as although they (especially the latter) are soft, they are slow to decay, and last from 6 to 8 years under heavy

traffic, or 10 years under light traffic. The objections to tapped pine (or timber from which the turpentine has been drawn) on the ground of impaired strength and inferior quality, have been proved to be groundless. There is likewise little reason for specifications that exclude longleaf pine grown north of South Carolina. Most of such timber grown in that region having already been cut, it is doubtful if it can be obtained in quantity, and the danger of substitution is therefore greater, especially as few persons can distinguish one species of Southern pine from the other in a lot of timber. Yellow pine is very extensively used, but will decay in about 6 years, though it will resist wear for 10 and even 12 years. It is often preferred to oak for bridge ties, as it does not warp or twist so much.

Red cedar and white cedar are good and durable timbers. They last for 10 or more years, but with heavy traffic their softness leads to cutting under the rails, and, like chestnut, the wood does not hold the spikes well on curves.

Hemlock is, as a rule, neither hard nor durable, and its life is very variable—from 4 to 7 years. It is extensively used on account of its cheapness, but is not good for first-class track, as it gets soft under the rails and at the spike holes. Spruce is about the same, lasting from 3 to 7 years. Tamarack or hackmatack (larch) is very commonly used, and will last from 5 to 10 years, or more.

Black cypress is much used in the South, where there is an abundant supply. It is soft but durable, lasting perhaps 10 years, if protected by metal tie-plates.

Redwood is extremely durable, but being soft it cuts badly under the rails. Its ordinary life on the Southern Pacific Ry. is from 5 years upward, depending upon the traffic, but some specimens of black redwood (the best quality), last over 20 years if properly protected. The ties usually fail by cutting out under the rail, which may be prevented by the use of metal tie-plates.

Red beech and red elm are fairly hard and durable, lasting 4 to 8 years. Black locust (which is a quick-growing timber) is good, but scarce, and has a life of about 7 to 10 years. Maple, hickory, ash, birch, cherry, butternut and white beech are of little value. Maple rots rapidly, and cherry has a tendency to split in spiking. Hickory is by no means durable. Mulberry and black walnut are used to a limited extent. Mesquite and catalapa are used in the Southwest.

Culls are second-class ties, used for inferior lines and sidetracks. The Allegheny Valley Ry. ranks red and black oak, pin oak, chestnut and cherry as second-class. The Cleveland, Cincinnati, Chicago & St. Louis Ry. provides that such ties must not vary from the standard specifications by more than 2½ ins. in length, 1 in. in thickness and 1 in. in width, and must not be so crooked that a line between the middle of the ends will pass outside the tie.

Full details respecting the structure and properties of tie timbers will be found in the report on "Tie Timbers," made by Mr. P. H. Dudley (Bulletin No. 1, Forestry Division, U. S. Dept. of Agriculture).

Ties on curves generally fail by respiking and the cutting under the rail before they are decayed, so that ties have to be taken out of curves as the gage cannot be maintained, although on tangents they would be good for perhaps 3 years more. Ties usually last longer in good, well-drained ballast, depending somewhat upon the form of cross-section. In

some sandy soils, however, they decay even quicker than in clay soil, the former supplying the warmth, air and moisture necessary for fermentation, while the latter excludes air and warmth. On the Minneapolis, St. Paul & Sault Ste. Marie Ry. ties in sand ballast (level with top of tie and shouldered out 12 ins. beyond the ends) give fully one year less service than in gravel ballast (sloped from 1 in. above tie at middle to 3 ins. below top of tie at the ends), and last best on the prairie lines with loam ballast (2 ins. above tie at the middle and sloped to bottom of tie at the ends). The traffic is lighter on the prairie lines. On the Missouri, Kansas & Texas Ry., ties of white, post and burr oak, cherry and sassafras have an average life of 6 to 7 years in natural soil, and 8 years in broken stone or gravel ballast, under the usual traffic conditions of Western roads. The Allegheny Valley Ry. finds the average life of white oak ties in broken stone ballast, which is kept well cleaned and drained, to be about 9 years, under a traffic of 4,500,000 tons per year. The Central Ry. of New Jersey finds that first-class oak and yellow pine ties last about 8 years on main line tracks in broken stone or engine cinders, and a little less in gravel. On the Union Pacific Ry. the average life in different localities and under different conditions is as follows:

Kansas Division; white oak, 6 years with heavy traffic and somewhat more with light traffic.

Colorado Division; natural soil ballast and moderate traffic; oak, 10 years; red spruce, 8 years; pine, 5 years.

Wyoming Division; white oak, 10 years; white cedar, 8 or 9 years; burnetised pine, 7 to 9 years; pine, 6 years in clay or gravel ballast and 5 years in sandy soil; Oregon fir and pine, 4 years in gravel, sand and loam, and 6 years in alkali earth.

Idaho Division; gravel or sandy ballast; native yellow pine ties, 6 to 8 years under heavy traffic, and 12 years under light traffic.

Pacific Division; gravel ballast and ordinary traffic; fir, 6 years; tamarack, 5 years; mountain pine, 4 years.

The idea that ties of old coarse timber are more liable to decay than those of young timber is not of general application. Young wood is the more apt to decay, owing to its larger proportion of albuminates, which form the food of the fungi. The young timber is sometimes assumed to be more tough and fibrous, and therefore better fitted to resist decay, but as the sapwood of such ties becomes rotten in a few years, the size is reduced so that they are renewed without regard to the soundness of the heart. Sound, mature, well-grown trees, yield more durable timber than either very young or very old trees. In hard woods, trees of rapid growth (indicated by broad annual rings), due to favorable conditions of soil and light, yield the most durable timber; while second growth timber of proper age and quality should in general be equal to first growth, or even preferable to it. In coniferous woods, however, slow growth (indicated by narrow rings) yields the better timber. The most durable timber for ties, therefore, is furnished by coniferous woods from comparatively poor soils, high altitudes and dense forest; and by hard woods from rich, deep, warm soils and open forest. In all cases within the same species, the heavier and denser wood is the most durable, and the heart wood is, of course, more durable than the sap wood. Winter is the best time for felling tie timber, especially if it is to be used without being seasoned, as it then contains less fermentable sap, and seasons more slowly and evenly before the temperature is warm enough to cause rot. The timber may rot with

or without fermentation, but usually does so without fermentation. With timber cut while in the leaf (as in the case of chestnut oak cut for tanbark), the trees should be left for two or three weeks before cutting to size. In the South, pine is often cut during the summer, a practice which is without any apparent good reason. Timber cut when the sap is at rest is more durable (mainly because fungus growth is then less active) than that cut when the sap is moving.

The seasoning of ties is of great importance, though not so generally recognized or practised as it should be, and ties properly piled and left to season for a year (or at least six months) are far superior to those put at once into the track. The ties should be barked and piled in rows of 8 to 12, spaced 6 ins. apart, and the rows separated by two ties at right angles to them. The pile should rest upon blocking, for if the ties are piled directly upon the ground, the fungus growth will soon attack the lower rows. The ties of the top row should be placed close together, and inclined so as to shed water. The piles should contain 50 to 100 ties each, and be at least 5 ft. apart, to allow an inspector to examine and mark the ties. If piled near the track, they should be at least 7 ft. from the rail and, whenever possible, on ground as high as or higher than the rails. Ties should not be piled in damp places in the woods where cut, but in dry, airy but shady places. More rapid seasoning may perhaps be effected by sinking the ties in running water for two weeks or more. On the Atchison, Topeka & Santa Fe Ry., it is found that pine ties cut in summer and placed in the track while green, last 3 years; if cut in winter they last 5 years when seasoned in air and 5½ years when seasoned in water. The difference in this case, however, is too small to warrant a definite favorable opinion, or to encourage the extra trouble. Large timbers, as for switch ties, headblocks, bridge stringers, etc., should be seasoned under cover, as otherwise the sun may cause them to season irregularly.

Hewed ties are very generally assumed to be superior to sawed ties, and this has led to a custom of insisting upon ties cut from trees that will make but one tie, or to insist that the cut shall make but one tie. There are two reasons why a sawed tie is apt to decay more rapidly than a hewed tie: (1) The saw does not make a sharp cut, but leaves a more or less woolly surface, which permits the accumulation of water and affords opportunity for fungus growth; this objection, however, may be avoided by the use of a planer-saw, which cuts and planes at the same time; (2) The sawing increases the end surfaces of the grain, as the cut cannot be kept parallel with the fibre, especially when the log is not quite straight, thus exposing bastard faces on the sides, which are simply partial cross-sections. Different roads have different opinions and experiences in this matter. Mr. W. W. Rich, Chief Engineer of the Minneapolis, St. Paul & Sault Ste. Marie Ry., prefers ties made from round timber, sawed on two sides, instead of hewed, as experience indicates that the former give longer service than the latter. This result was not expected and is contrary to tradition. The Cleveland, Cincinnati, Chicago & St. Louis Ry. requires sawed ties to be 9 ins. wide, instead of 8 ins. as specified for hewed ties. Sawed ties are being more and more used, and if treated by preservative processes the two objections above noted are eliminated. The objections to split ties are also passing away, except that of the quicker and deeper season checking which takes place in a split tie with the heart on one side. Warped and twisted ties should not be used, as they are liable to rock in the ballast.

The ties should invariably be stripped of bark, as, if this is not done, the bark will hold water in the ballast and against the tie; while when it eventually becomes loose it makes a very unsightly track and interferes with proper tamping. It also, when loose, allows the track to shift, the ties slipping out of the smooth bark, while the ballast holds the bark instead of the tie. They should be of uniform size, and those of the same kind should, as far as possible, be kept together to ensure approximate uniformity in wear.

Ties should be made from sound, thrifty, live or green timber, free from loose or rotten knots, wormholes, dry rot, wind shakes, splits or other imperfections which affect their strength or durability. They should have no sapwood on either face, and not more than 1 in. on the edges or corners. They should be hewed or sawed with the faces perfectly true and parallel, should be of the exact thickness specified, the faces out of wind, smooth and free from any inequality of surface, deep or bad score marks or splinters, and should be not more than 3 ins. out of straight in any direction. The specifications should be carefully and intelligently prepared, and their requirements should be rigidly enforced, inspectors being instructed to reject all ties not up to the required quality or dimensions, and being sustained in this by their superior officers. Accepted ties should be distinctly marked with paint by the inspector.

There are two principal elements governing the life of a tie: 1, Its resistance to natural decay; 2. Its resistance to the wear resulting from the cutting and abrading action of the rail. The direct compression under the rail is too slight to enter into consideration. Ties in service are injured, destroyed or rendered unserviceable by three principal causes: 1, Mechanical disintegration of fibers and the abrasion of fibers under the rails; 2, Injury by spiking and respiking; 3, General or natural decay of the wood, induced by fungi. Under average and ordinary conditions on American railways, ties have to be renewed more on account of the cutting and abrasion (and consequent local rot) under the rails, than on account of natural decay. Mr. Katte, Chief Engineer of the New York Central Ry., estimates that 20% of the ties taken out are removed on account of cutting and hammering; from 10 to 15% being reported as "crushed or broomed," and from 4 to 10% as "cut out" by respiking. This cutting action, due to the slight motion of the rail and the loosening and wearing of the fibers weakened by rot under the rails, may be largely reduced by better rail fastenings to hold the rails and ties more firmly together. It may also be almost entirely eliminated by the use of suitable metal tie-plates, which thus effect a decided economy in making cheaper and softer woods practically equal to the more expensive and harder woods. Ties will wear out more quickly on curves on account of the lateral strain on the rails forcing the spikes back, enlarging the spike holes and reducing the frictional hold of the spike in the tie. They also wear out more quickly on heavy grades where the engines use sand, and here again metal tie-plates help to prevent the cutting.

The natural decay of the tie as a whole depends largely upon the wood, ballast, climate, etc. It usually begins first at the ends and second at the rail seats. The first is a normal trouble, and is much hastened by season checking, and may be overcome by painting the ends with a resin or cheap paint, so as to cause a slower exchange of moisture. The true economical reform in railway ties, before metal track is considered, re-

quires preservation by impregnation in combination with the use of metal tie-plates. If impregnation is considered too expensive, even in view of the economies to be attained thereby, it would be wise to at least paint the ends or dip the ends in the cheap resin now thrown away at the turpentine distilleries in the South. This resin would also be an excellent material for closing old spike holes, as the present method of plugging with wood is often a waste of time and energy. Boring the holes for spikes would prevent much checking, and if the size of hole is proportioned to that of the spike it should increase the holding power. The Southern Pacific Ry. has a machine for boring simultaneously four holes for screw spikes in redwood ties. Good results are also said to have been attained by "spotting" the rail seats so that the seat will be on the same incline as the car wheel tires, and this may be done by machine. This practice is common in Europe, where, however, the wheels have a steeper coning, the inclination being usually 1 in 20, while in this country it is 1 in 38. Ties should never be moved by sticking a pick into them to pull them into place, as such practice forms places where rot may start.

As to size, the small ties usually resist decay better than large ones, and with tie-plates to prevent cutting, such ties may advisedly be used. It is a well-established experience, for instance, that smaller fence rails decay less rapidly than large ones. The ties should be of uniform size, the specifications being rigidly adhered to, and ties of the same kind should as far as possible be kept together in order to insure uniformity in wear. The thickness varies from 5 to 8 ins., but should never be less than 6 ins., as the ordinary 5½-in. spike goes about 5 ins. into the wood, besides which the deeper tie has greater stiffness to resist transverse bending. If the thickness is not uniform, in renewals the tie beds must be raised or lowered, thus disturbing the stability. The width is from 6 to 10 (or even 12) ins., but 8 ins. is a very good width to give a good seat to the rail and a good bed in the ballast. Where there is any difference the wider ones should be used for joint and shoulder ties. Ties of excessive width are awkward to handle, require too much digging in renewals, and are liable to rock. The ties should be of uniform thickness and width, the former to insure a uniform bearing in the ballast, and the latter to give a regular and even bearing to the rail. and both to form an easy riding track and to reduce the disturbance of the ballast bed in renewals as much as possible. The length ranges from 8 to 10 ft., the latter being used on some parts of the Southern Pacific Ry., Louisville & Nashville Ry., etc., but 8 ft. and 8 ft. 6 ins. are the common lengths in first-class tracks, the longer ones being used mainly in poor ballast and in swampy districts. The Canadian Pacific Ry. uses ties 6½ ins. thick, 6 ins. wide and 8 ft. long, except between Montreal and Smith's Falls, where they are 9 ft. long, on account of the heavy traffic. For ordinary track, however, it is doubtful whether an increase in length beyond 8 ft. 6 ins. gives any effective bearing or is of any real use. The length should be uniform, for it is easy to cut them to the right length, and this will be done if the inspector insists upon it. Where it is not uniform, the ends should be lined on one side of the track. To facilitate this, a notch should be cut on the handle of the spike maul at the right distance (according to length of tie and width of rail base) and in placing the tie the end of the handle is placed against the outer edge of rail and the end of the tie drawn to the notch. Square sawed timbers of varying length are used at frogs and

switches, and square sawed ties on bridges. The standard sizes of ties on a few roads are given in Table No. 2:

TABLE NO. 2.—SIZE OF TIES.

Railway.	Thickness, ins.	Wdth, ins.	Lngth, ft.	Railway.	Thickness, ins.	Wdth, ins.	Lngth, ft.
Allegheny Valley	7	9	8½	Louisville & Nashville[1]	7	9	8½
Central of N. J.	6	6	8½	Mo., Kan. & Tex.	6	8	8
Chic. & Northwestern	6	8	8	N., C. & St. L.	7	8	8½
C., C., C. & St. L.	7	8	8	Pittsburg & Lake Erie.	7	9	8½
Illinois Central	6	8	8	Union Pacific[2]	6	8	8
New York Central	7	8	8	Union Pacific[3]	7	8	8

[1]Sometimes 9 ft. [2]Oak and cedar. [3]Pine, fir and spruce.

The spacing of ties varies from 2,240 to 3,200 per mile, or from 14 to 18 per 30-ft. rail, and it should not be less than 16 for a 75-lb. rail, though it may be less with heavier rails. The Pennsylvania Ry. uses 14 wide-faced ties on main track, and 12 for side tracks and yards; Chesapeake & Ohio Ry., 18; Central Ry. of New Jersey, 16; Southern Pacific Ry., 17 and 18 on main line tangents and curves, and 15 on branch lines. They should not be uniformly spaced, but the joint and shoulder ties should be somewhat closer together than the intermediates, so as to give an increased bearing at the rail ends, where the tendency to deflection of the rail is greater. Joint ties may be 10 to 16 ins. apart in the clear, and intermediate ties 16 to 30 ins., according to the rail and traffic. Some roads specify a certain number of linear inches of tie-bearing per rail, the Duluth & Iron Range Ry. specifying not less than 130 ins. On the Pennsylvania Ry. the standard spacing of joint ties is 10 ins., as it is considered that with less than this the tamping cannot be properly done. A vote taken from 1,033 foremen on this road, gave 82% in favor of 10 ins. The Southern Pacific Ry. spaces the ties 14 ins. c. to c. at joints, and 20 to 24 ins. intermediate, according to the number per mile. A clear spacing at joints is better than a measurement center to center. The New York Central Ry. spaces ties 25 ins. apart c. to c., and 15 ins. c. to c. at the three-tie joints. Some roads space ties by the width of a shovel, without regard to any fixed number of ties per rail, this practice being generally followed where the rails are light and the traffic is heavy. For such tracks it is considered that nearly 50% of the length of the rail should be supported on ties, but the practice of making the spacing equal to the width of the ties is not to be recommended. The ties should not be less than 10 ins. apart in the clear, except at three-tie joints, where they may be 6 to 8 ins. apart; and on bridge floors, where they should not be more than 4 ins. apart. The number of ties per mile of single track for various spacings is given in Table No. 3:

TABLE NO. 3.—NUMBER OF TIES PER MILE.

		No. of ties per mile.
No. of ties per 30-ft. rail	12	2,112
" " " " " "	14	2,464
" " " " " "	16	2,816
" " " " " "	18	3,168
Ties spaced c. to c.	24 ins.	2,644
" " " " "	28 "	2,348
" " " " "	30 "	2,115
" " " " "	33 "	1,921
" " " " "	36 "	1,761

As the spacing of the ties in relation to rail deflection is a matter often referred to, it may be explained that the deflection for a given rail and load varies practically as the cube of the tie spacing; therefore, if we take 1 as the deflection for ties 24 ins. c. to c., then for ties 30 and 36 ins. c. to c. it will be 1.9 and 3.4 respectively.

Longitudinal timbers instead of cross-ties are used in Europe to a very limited extent, but are quite generally used on bridges in many countries. They are used on the Victoria Bridge, which carries the Grand Trunk Ry. over the St. Lawrence River at Montreal, and the Long Bridge, which carries the Pennsylvania Ry. over the Potomac River at Washington, D. C. They are also being used to some extent for tracks in terminal stations. In the Louisville & Nashville Ry. station at Louisville, Ky., the 80-lb. rails are laid upon continuous iron plates upon longitudinal timbers 12 x 12 ins., which rest upon wooden cross ties. The rails are held by spikes passing through the iron plates. In the Broad St. station of the Pennsylvania Ry., at Philadelphia, Pa., the rails rest on wooden blocks 2 ins. thick (19 blocks to a rail length) placed on longitudinal timbers, which in turn rest upon cross ties. There are 11 ties to a rail length, with a tie under each rail joint, but there is no blocking under the rail joints. The stone ballast is level with the tops of these ties.

Tie Renewals.

The tie renewals are too frequently considered as a comparatively unimportant item in the expense account of maintenance of way, but in point of fact the average cost of tie renewals on many roads far exceeds that of rail renewals, and shows a tendency to increase. for the following reasons: (1) Gradual increase in price of ties, owing to the increased value of timber as the supply becomes exhausted, and to the increased haul as sources of supply become more distant. (2) The marketing of the best timber, so that the poorer qualities must be cut for ties, giving consequently inferior service, especially if ties from young and undersized trees are accepted. (3) Less rigid inspection and the acceptance of inferior ties. (4) Greater tendency to cutting and local rot under the rails, due to increased wheel loads and growing traffic. (5) Spike killing, caused by regaging, redriving loosened spikes, etc. The renewals average about 250 to 350 ties per mile per year for main tracks, and 200 to 250 for side tracks, but these figures are reduced very considerably where treated ties and metal tie-plates are used. A road which has to renew its ties in 6 years is at a great disadvantage as compared with one whose ties last 12 years, as the former must figure into its expense account almost double the cost for material, besides the additional track labor necessary to do the work, while during the interval it cannot have as good a track as the latter.

In a paper on "The Increasing Cost of Railway Tie Renewals" (Transactions, Am. Soc. Civil Engrs., December, 1892), Mr. Reece pointed out that while a few years ago the cost of such renewals was but a fraction of the rail renewals, now the figures are reversed, and the tie renewals offer an opportunity for large reductions in expenses. Close attention has been paid to the purchase of rails, to their design, manufacture, life, wear, etc., while the qualities and properties of the ties have too often been comparatively neglected. Taking the cost of rail renewals at 100, that of tie renewals often ranges from 110 to 400. There is a very general failure on the part of executive officers to appreciate the expenses involved in the renewals, especially if the expense of labor for removing the old and putting in the new ties is taken into account, as of course it should be. As a logical consequence of the comparative neglect, tie-expenses are continually increasing, while much of the expense of labor expended on the track can be charged to the deterioration of track due to the softening of ties from incipient decay, and to the

more frequent renewals of ties, the cost of putting a tie in the track being from 20 to 50% of its first cost.

If the officers of a railway grant requisitions for ties liberally and without question there will be a tendency to take out ties before they have given their proper service; while, on the other hand, if the officers are parsimonious and habitually cut down the requisitions there will be many ties left too long in the track, unless the requisitions are "padded" to allow for the probable cutting down. A marked saving in renewals may be effected by systematized checks for preventing the premature removal of comparatively sound ties from the track, a practice which many section foremen have. Attention to this point has on some roads been attended with very satisfactory results. Well devised plans should be instituted for preparing careful estimates of each season's requirements, and the practice varies greatly, some roads being very careful and others very careless in this particular. On the Louisville & Nashville Ry. the custom is to prepare estimates prior to July 1, showing the number of ties required on each division, the estimates being made from actual count of ties in the track that should properly be removed during the next twelve months. The count is made by the section foremen, checked and certified to by the respective supervisors and roadmasters, approved by the superintendents after investigation, and forwarded by them to the chief engineer, who is supposed to have a general knowledge of the condition of ties on the entire line. If the estimates differ widely from what he expected they are returned for further investigation, and revised if necessary. Finally, the requisitions are forwarded to the general manager, with a request for authority to contract for the ties needed, and with them is sent a statement showing the average number of ties used per mile on each division during the ten years previous, and where the number called for appears excessive as compared with the average, explanation is made. On the Nashville, Chattanooga & St. Louis Ry. the ties are inspected and counted for renewal by the section foremen, under the supervision of the roadmaster. On this road the renewals are under the Transportation Department instead of the chief engineer, which is not a good practice. On the Chicago & Northwestern Ry. each foreman marks with an axe the ties which he thinks should be removed, after which the roadmasters go over their divisions to see whether the foremen's judgment is correct, and they generally cut down the number very considerably.

The section foreman should determine by actual count, and not by a guess estimate, the number of ties which he considers he will need on each mile of his section, marking the ties and reporting the number to the roadmaster. The latter should personally verify the estimate, in company with the foreman, for while ties are often left in too long, yet many foremen condemn ties which are still good. Ties should never be renewed without permission, and those taken out should not be burned or removed from the right of way until inspected by some officer thoroughly and practically familiar with the use of ties and the amount of work that can safely be got out of them. On some roads the foremen are forbidden to remove ties having more than 4 ins. of good timber left under the rail. Records should be kept of the annual renewals, and if a very high requisition is made in any one year investigation should be made as to the reason therefor.

It is an excellent plan to mark the ties in some way, so that their

length of service can be seen at once, and a record kept of them. Then, if ties are found to be taken out after only a few years' service, the reason should be investigated. Of course, this marking should not be made a basis for renewals, the ties being still, as ordinarily, taken out only when examination shows the necessity of so doing. The renewals are made irrespective of the marks, because the great difference in the enduring qualities of ties apparently from the same lot and place, make it quite possible that one tie may become unfit for further service in 4 or 5 years, while its neighbors from the same lot may be good for 8 years' service. On the Allegheny Valley Ry. the system of marking is by cutting a small V-shaped notch with an adze or axe in the edge of the tie at the time of placing it in the track, the position of the notch indicating the year. The ties are hauled in from the woods in the winter months and are, as a rule, placed in the track early in the year, so that a glance at the marking while passing along the track will show the observer both the age of the tie from the tree and its length of service. The section foremen make simple reports of the ties taken out and their age as indicated by the marks, which reports are tabulated and filed, forming a record of the average life of the ties. The number of ties estimated for renewals is advertised for by the purchasing agent, who inspects them for acceptance or rejection. On the Cleveland Division of the Cleveland, Cincinnati, Chicago & St. Louis Ry., it has been the practice to mark the ties when they are put in the track, as the ballast is of stone, slag, gravel and cinders, and this marking enables the officers to secure definite information in regard to the length of service and life in the different kinds of ballast. For this purpose a stamp is used with letters about 1½ ins. long, giving the year. The stamp weighs about 3½ lbs., and the marking is done by a blow as with a sledge or hammer, the mark being made on the top and the south end of the tie. In Germany it has been found that the impression made by such hammer stamps on preserved ties become effaced before the time for renewal, and nails or tacks with distinguishing figures or marks were therefore substituted. The Atchison, Topeka & Santa Fe Ry. stamps the date of treatment on its burnetised ties.

Old ties may be used for fence-posts, cribbing in wet slopes and for various incidental uses, but are usually burned on the right of way or used for fuel. Old ties and bridge timbers intended for use as fuel may be economically cut up by machinery. The Pittsburg, Fort Wayne & Chicago Ry. has a machine for this purpose, which resembles a shearing machine, with a vertical moving blade. The upper (moving) blade is set about 1 in. out of line from the lower (fixed) blade, thus allowing space for hard substances, such as old spikes, to pass through without injuring the blades. The machine will cut timbers 8 x 12 ins., and the pieces are so crushed in cutting that they can easily be split lengthwise with an axe if desired.

Preservative Processes.

The use of preservative processes for wooden ties as a means of securing improved track with reduced maintenance expenses, has not been given the careful attention in this country which its importance warrants, and though the resultant practical economies have been amply proved in other countries they have been but indifferently recognized here, with some important exceptions. This is due largely to the failure to prop-

erly appreciate the expenses involved in tie-renewals, as already noted, and partly to a desire on the part of each road to see what results other roads obtain with treated ties before committing itself to expenditures in this direction; while reports of the satisfactory results obtained in foreign countries are apt to be regarded with some degree of distrust on account of the difference of conditions of railway construction and operation. Nevertheless, there is in this country evidence enough as to the efficiency of preservative processes and the economies resulting from their use. As to the first cost of the ties, it must be noted that the use of preservative processes often enables a cheaper and (if untreated) inferior timber to be used at about the same cost as (or even less cost than) untreated ties of more expensive wood, while the increased life of the treated tie will reduce the cost of ties as distributed over a term of years, and will also materially reduce the expenses for maintenance of way. In very many cases ties are cut from first class material which might far better be left to be available for other industrial purposes, when treated ties of a lower quality of timber would really be better and more economical.

This question of the relative cost and ultimate economy of treated and untreated ties is a subject which comes up periodically for discussion. It seems, now, to be pretty evident that while engineers very generally recognize the practical and financial advantages of treated ties, the managers and executive officers of railways are, as a rule, able to realize only the extra first cost of the tie, and do not yet sufficiently appreciate the economies due to increased life of ties and the saving of labor in tie renewals, so that the engineers have a campaign of education to conduct before they can expect to bring about the general use of treated ties. From a detailed estimate prepared by a railway manager of the relative cost of southern pine ties the following is taken: The specifications for untreated ties of southern pine generally call for all heart pitch pine, of such dimensions that from 22 to 23 ties are equivalent to about 1,000 ft. B. M. To cut three such ties from one log requires a tree measuring at the small end from 12½ to 12 ins. diameter, about 30 ft. long. Such logs are worth for saw logs from 30 to 35 cts. each, and are becoming more expensive and farther removed from the lines of railways and water courses. The logs generally used for ties are such as are defective for sawmill purposes, and are sold standing in the woods at from 10 to 15 cts. each. This makes the cost of the timber about 5 cts. per tie. The cutting of a tie costs from 12½ to 15 cts., the hauling from the woods to the railway or landing costs from 3 to 5 cts., and to this must be added the railway freight or lighterage, which ranges from 5 to 15 cts. per tie, making the cost of pitch pine ties laid down at a southern port from 25½ to 40 cts. each. The freight on ties from southern ports to New York ranges between 18 and 21 cts. each, and adding this to the cost at the southern port would make the cost of the ties at New York from 46 to 61 cts. each. As in the above figures no allowance is made for expense of inspection or percentage of loss and profit, it is safe to say that the cost of a tie at New York under ordinary circumstances should be placed at from 55 to 70 cts.

Such a tie will do service in the south for about 5 years, and in the north for about 7 years, but such a tie, used in the north, is not destroyed by decay only, the wear of the rail and the checking of the timber being quite as destructive as decay. The checking of the pitch pine tie is one of its great-

est defects; the checks will not only loosen the spikes but will cause openings for moisture to penetrate the interior of the tie, causing its decay during the summer; water freezing in the checks during the winter will increase them very much, thus hastening the destruction of the tie.

For creosoted ties pitch pine is not suitable, as it would not absorb a sufficient quantity of the oil. Short leaf yellow pine, which has a much more open grain, is the wood to be used for creosoted ties. This timber grows near the coast and water courses of South Carolina, Georgia and Florida in great abundance and very rapidly. For sawmill timber it is in little or no demand, and consequently as a raw material it is very much cheaper than heart or pitch pine. It is not as hard and durable as pitch pine in its natural state, but it does not check, and can be made hard and more durable than pitch pine by creosoting. It is in easy reach of water courses and can be laid down at any southern port for considerably less money than pitch pine. This wood resembles very much the Baltic fir, which is so extensively used for ties in Europe, and which is usually treated by some preservative process, of which creosoting takes the front rank. In Europe a good deal of attention is paid to the time when timber is cut and also to the handling and treatment of the same afterwards. The timber is always cut when the sap is not rising and what little sap and moisture is left in the timber is removed by either natural or artificial seasoning.

The cost of the material in a southern short-leaf pine tie is about 3 cts.; cutting, 12½ cts.; hauling to landing, 1½ to 3 cts.: transportation to port, 3 to 5 cts.; cost at port, 20 to 23½ cts.; freight to New York, 18 to 21 cts., making the price of tie at New York from 38 to 45 cts.; adding to this the expense of inspection, percentage of loss and profit at same ratio would make the cost of such a tie under ordinary conditions from 48 to 54 cts.

To creosote such a tie would increase its price by about 40 cts., or a creosoted short-leaf-pine tie would cost at New York about 85 to 94 cts. From a comparison of the life of a creosoted tie with that of a pitch pine tie it seems that it would be economy to use the treated ties altogether. In the yard of the Houston & Texas Central Ry., at Houston, Tex., creosoted ties were used in a place where the traffic was heaviest; these ties were cut from Texas scrub pine, a material much inferior to southern short-leaf pine. After eight years' use these ties were perfectly sound, the cutting of the rail was hardly perceptible, and all the little checks in the tie had been filled up by oil oozing into them, which thus kept the water from entering. A further advantage of creosoted ties is that they hold the spikes much firmer than uncreosoted ties; a slight corrosion seems to take place on the side of the spike, which after a few years increases its hold so much that when a spike is pulled out of a creosoted tie the head generally breaks off.

Let us now take the average of the figures as given in the above extract, and see what is the actual cost per annum of each tie.

	Untreated tie.	Treated tie.
Average first cost, cts.	51	90
Average life, years	6	12
Annual interest charge on first cost (4%), cts.	2	3.6
Annual outlay for a sinking fund which will replace tie at end of its life (interest at 4%), cts.	7.7	5.6
Total cost per tie per annum, cts.	9.7	9.5

It will be seen from the above that the actual annual cost of the two ties, on a road which can borrow money at 4%, is practically the same. With interest at 6% the treated tie would be more expensive than the other by 0.36 ct. per annum.

On roads where the above conditions prevail, therefore, the economy in the use of treated ties will arise in the economy of labor expended in track maintenance, rather than in the cost of the ties themselves. But on roads located in warm climates, where ordinary ties have a short life, or those located in regions so remote from a timber supply that ordinary ties are very expensive, there may also be a saving in the cost of the ties themselves. As a matter of fact the railway companies which have done most in the way of tie preservation are those which are located in the far south or on the treeless plains of the west.

In view of the labor and expense of replacing ties in street railway tracks, it may well be expected that street railway companies will soon find it to their advantage to adopt treated ties for their tracks, or even to adopt some form of metal tie.

Even if treated ties cost twice as much, and lasted only twice as long as untreated ties (which are exceptionally unfavorable conditions), there would still be an economy effected by the use of the former, due to the consequent saving in cost of renewals, to say nothing of the improved condition of track, and the reduction in track work where the road is not continually or annually disturbed for tie renewals. Untreated ties have a most irregular life; and as the average number of ties renewed annually is from 250 to 350 per mile in main track, there is probably hardly a rail length of main track which has not at least one tie renewed each year. Besides the first cost of the new tie (against which there is no credit for "value of old material," as old ties are usually absolutely valueless), there is the direct cost of removing the old tie and putting in the new one, together with a probable loss of at least one of the four old spikes (which if broken, or bent so as to be useless, is as likely to be thrown away as to be sent to the scrap pile, involving another incidental expense).

It is practically impossible to get the new tie at once as well and firmly imbedded as the old one, which has probably been cut into by the new rail so as to reduce its thickness. When the new tie is in place, therefore, it will prove to be tight (raising the rail slightly above the normal surface) or loose (allowing the rail to deflect or bend before the tie gives it proper support). If we consider such conditions as occurring once on each rail length of track, it will be seen that a certain increase in wear of rails and wheels, and in the motion of cars, must result. These effects will continue until the traffic (pounding from above) and the section men (tamping from below) have restored the normal surface of the track, as far as may be, in view of the increased wear which has already been sustained. It will be evident that if all this expense and work can be made to occur only once in two, three or four years, instead of every year, there will be a saving in operating expenses, distributed partly in the roadway department and partly in the equipment and transportation departments.

To arrive at any definite conclusion in regard to the advisability of using treated ties on any particular railway, it is necessary for the officers of the railway to carefully and thoroughly consider for themselves the relations of expenses for ties and tie renewals and track work, and the cost and life of

treated and untreated ties under the conditions of location and traffic of that particular road. The economy results not only from the above means, but also from the reduced labor for and cost of maintenance, and the improved surface of track due to reduction in renewals; for, under ordinary conditions, the track has hardly been got into good surface on a settled bed than it is disturbed by renewals of some of the ties, as noted above. Probably the best and most economical practice of roads carrying heavy traffic will be to use treated ties protected from the cutting action of the rail by means of metal tie-plates, as noted further on.

The Chicago, Rock Island & Pacific Ry., in 1886, laid 50,200 oak ties and 21,850 burnetized hemlock ties on new track west of the Missouri River, and, in 1893, there had been renewed 14.56% of the untreated and 3.16% of the treated ties.

The Southern Pacific Ry., which has been using burnetized ties since 1887, found that by the use of these ties the tie-renewals were reduced from 243 per mile of track (including sidings) in 1891, to 240 in 1892, 205 in 1893, and 145 in 1894. This road has a treating plant with cylinders 6 ft. diameter and 110 ft. long, and has also a portable plant for the same purpose. The timbers treated are long-leaf and short-leaf yellow pine, from eastern Texas and western Louisiana. Chloride of zinc is used for track ties and creosote for bridge ties, bridge timbers, piles, etc. Descriptions of these plants will be found in "Engineering News," New York, April 26, 1894, and April 4, 1895.

In most of the processes the principle of the treatment is to extract the sap and replace it by a material which will fill the cells of the wood and prevent fermentation and decay. The vulcanizing process, however, is claimed to effect a chemical change in the constituents of the sap itself, being practically a seasoning process carried to extremes. The timber should, for most processes (see Boucherie process), be thoroughly seasoned before treatment, and it is waste of time and money to hurriedly treat timber required for immediate use, though this is sometimes done, owing to the contracts for ties not being placed in proper time. Whatever process is used, it is absolutely essential that it should be carried out carefully and thoroughly, if the best results are to be obtained. For this reason, among others, several large railway companies prefer to operate their own works, which is a good plan, and likely to give satisfactory and economical results if the work is carried on systematically. The various processes used, and their efficiency and economy, etc., have been very fully given in the exhaustive report of a committee of the American Society of Civil Engineers (1885), and by Mr. P. H. Dudley, and the writer in Bulletins No. 1 and No. 9 of the Forestry Division, U. S. Department of Agriculture.

Creosoting.—This is one of the best and most successful processes, and is very extensively used abroad, but in this country its introduction has been hindered by the higher cost of creosote oil and the consequent expense of the treated ties. The process consists essentially in (1) placing the ties in a large iron cylinder and exhausting the air so as to extract the sap, (2) heating the ties by steam to soften the cell walls and dissolve the contents of the cells, and then (3) filling the cylinder with hot creosote oil and applying pressure to force it into the wood. The creosote is heated to make it sufficiently fluid to enter the wood. Two kinds of oil are used: dead oil of coal tar, and wood creosote oil. The dead oil is obtained by the distillation of coal tar, and its principal preservative constituent is naphtha-

line, which melts only at about 175° F., so that if liquefied during the treatment it penetrates the wood cells, and then becomes solidified and is permanently fixed. Acridine is an important constituent, and (like naphthaline) remains permanently. The tar acids, which were formerly supposed to induce coagulation of the albumen in the tie, and thereby to be the principal preservative, are found to disappear in a comparatively short time. Wood creosote oil is obtained by the destructive distillation of pine, and contains paraffin oils as its principal preservative. It is less dense than the dead oil, and is so much cheaper that if equally efficient it would very much advance the use of preserved ties, but the practical trials have not been of sufficient extent to be conclusive. A creosoting company which used this material, but abandoned it in favor of dead oil, stated that its life as an antiseptic is limited on account of its being more soluble than the dead oil. About 12 lbs. per cu. ft. were used for pine, and the treated ties cost about three times as much as untreated ties. This company gave the analysis of wood creosote oil as follows: tar, 10%; tar acids, 36.7%; neutral oils (mostly paraffin oils), 53.3%. In all kinds of creosote some engineers prefer the heavier and some the lighter oils.

The ties should be well seasoned before treatment, as little creosote can be forced into a wet tie, while a thoroughly dry tie will readily absorb a large quantity of oil, which, when solidified by exposure, no moisture in the air or ground can succeed in removing. The sap should be thoroughly extracted, and if the oil is not well forced into the tie, the wear of the rail may cut through and lead to decay of the unimpregnated part. The natural decay also starts in the interior, which is not so thoroughly penetrated by the preservative. For this reason, too, all cutting, framing, boring, etc., should be done before the tie or timber is creosoted. A general objection has been that creosoting softens the wood and renders it more easily cut out by the rail. This effect, however, is only temporary, and if the ties are stacked for about six weeks after treatment, no trouble is likely to be experienced. As to the quality of the oil, the Southern Pacific Ry. merely requires that it shall not have been treated for extraction of the aniline products, as this has been found to render the creosote less serviceable as a preservative. The Lehigh Valley Creosoting Co. uses a dead oil with a hydrometer weight of 1,050 at 60° F., making the weight about 8.7 lbs. per gallon. On the Great Northern Ry. (Ireland), the creosote in the cylinder is heated to 120° (to dissolve the naphthaline and render the oil fluid), and a pressure of 100 lbs. is carried for three hours; while on the Lancashire & Yorkshire Ry. (England), with the same temperature, a pressure of 150 lbs. is carried for 50 minutes (see "English Railway Track," E. E. Russell Tratman; Transactions, American Society of Civil Engineers, March, 1888).

The details of operation at the works of the Southern Pacific Ry., near Houston, Tex., are as follows:

After a charge of ties on small iron cars has been run in and the cylinder sealed, a vacuum of 22 to 24 ins. is created in the cylinder, requiring about 10 minutes. Live steam is then turned in, destroying the vacuum and giving a temperature of about 125° F.; this requires from 15 to 20 minutes. The vacuum pump is again started and a vacuum created to open the pores of the wood and to have the cylinders heated uniformly; this requires 15 to 20 minutes. Live steam is again turned on and the pres-

sure raised to 30 lbs. in about 40 minutes, and maintained from six to eight hours, according to the size and kind of timber, care being taken to prevent the temperature from exceeding 250° F. Steam is then blown off, requiring 40 minutes, and a vacuum created for the third time, requiring about 90 minutes for a vacuum of 24 to 26 ins. The superheating pipes in the cylinder are used to maintain a temperature of 225° on the timber during these 130 minutes, and during the four to six hours for which the vacuum is maintained. The cylinders are then filled with creosote oil at a temperature of about 170°; this requires 35 to 40 minutes. The pumps are then started, and the pressure is raised to 80 or 100 lbs. per sq. in., and maintained from one to two hours, according to the size and kind of the timber. The oil is then drawn off, the cylinder opened, the train pulled out, and another charge run in; this requires 40 to 60 minutes. The average time of treatment is from 18 to 20 hours; the average absorption is 1¼ gallons per cu. ft., and the average cost is from $12.50 to $14.50 per 1,000 ft. B. M. For piles, no vacuum is created, but the timber is boiled in the dead oil at a pressure of 120 lbs., and a temperature of 240° F., the treatment lasting for 12 to 14 hours. As the checking occurs during the treatment the resulting cracks are well filled with oil.

The Pacific Division of the Southern Pacific Ry. has a portable plant for treating timber, which is set up on a side track in the woods where the ties are being cut. A description of this will be found in "Engineering News," New York, April 4, 1895.

Burnetizing.—This process (also known as the zinc-chloride process) consists in impregnating the ties with a solution of metallic zinc in hydrochloric acid, the methods of operation being similar to those for creosoting. Burnetized hemlock and tamarack ties were laid in 1866 on the Chicago, Rock Island & Pacific Ry., near Chicago, and in 1882, after 16 years' heavy traffic, about 75% were still in the track, and the rails had not cut them more than white oak ties. The Union Pacific Ry. treated about 208,000 ties at its own works from 1866 to 1887, but it is estimated that the treatment increased the life only about three years. The treatment was abandoned on account of its cost as compared with the slight increase in the life and the cost of transporting the ties from the forests to the treating plant and back to the distributing point. It was therefore found to be more economical to use metal tie-plates on untreated ties.

The Atchison, Topeka & Santa Fe Ry. has a plant of its own, using a solution of 1 lb. of chloride of zinc to 4 gallons of water. The green ties cost about 12 cts. each, while the treatment costs 25 cts. per tie. The zinc solution, unlike creosote, should not be heated. The solution has the property of hardening the wood, but affects its strength and elasticity, making it brittle, especially if a solution of over 3% in strength is used, so that the process is not considered desirable for bridge timbers or piles. The ties are said to be liable to split if exposed to a lot of sun. The material in the ties after treatment is somewhat soluble, and for use in wet or damp locations an auxiliary treatment to prevent the leaching or washing-out of the zinc is often resorted to, as noted further on. In the treatment, care should be taken to charge the cylinder with ties of as nearly as possible the same age, as if green ties and ties seasoned for about 6 months are subject to the same treatment, the percentage of absorp-

tion of the latter will be very much greater than that of the unseasoned ties.

The process of burnetizing, as practised at the works of the Southern Pacific Ry. is very similar to that of creosoting (already described). The steam is held at the 30 lbs. pressure for 3½ to 6 hours, instead of 6 to 8 hours, depending entirely upon the kind and condition of the timber. After the third vacuum, the cylinder is filled with the zinc solution, requiring about 25 minutes, and a pressure of 80 to 100 lbs. per sq. in. is then maintained for 1 to 1½ hours, when the solution is drawn off, requiring about 20 minutes. The solution contains 1.7% of the chloride of zinc, which corresponds to 2½° on the scale of the Beaume hydrometer. The railway purchases a crude concentrated solution of the chloride, of 50° density Beaume, slightly discolored by iron to the extent of not over 1 to 2%, and this is diluted for use to a density of 2½°. The average time of treatment is 11 to 12 hours; the average absorption is 4½ gallons per tie, and the average cost of treatment for a tie 6 × 8 ins. and 8 ft. long is from 9½ to 12 cts. After being treated the ties are stacked in piles, and are not put in the track until they have been thus seasoned for 6 to 8 weeks. The date of treatment is stamped on the end of the tie. Only sap ties are treated, and these are purchased at mills in eastern Texas for about 23 cts. each, the average life of an untreated sap tie being only about 2½ years. Burnetized pine ties in Texas cost about 34 cts. each. They have a long life and decay is almost unknown. The burnetized ties are not given a second treatment to prevent the washing out of the zinc solution, as they are used only in thoroughly ballasted track, which drains well, while the majority of the ties are laid west of San Antonio, Tex., in a very dry region where there is no trouble at all from such washing out. After an investigation of the Wellhouse process, as used on other railways, it was concluded that under these circumstances the benefits were not sufficient to warrant the paying of a royalty for using this latter process.

Wellhouse and Other Zinc-Auxiliary Processes.—An objection to the burnetizing process, especially when the ties are to be used in wet or damp districts, is that the zinc-chloride, being soluble, may be washed or leached out, this action being caused more by damp atmosphere and ballast than by heavy rains. The ballast may also contain chemical constituents which will change the chloride of zinc into oxide of zinc, which latter is a non-antiseptic. To overcome this objection several auxiliary or combination processes have been introduced. The best known of these is the Wellhouse, or zinc-tannin process, which has been somewhat extensively applied in this country. To the zinc solution, as admitted to the cylinder, is added glue, in the proportion of 2 lbs. of glue to 100 gallons of the solution, and a pressure of 100 lbs. per sq. in. is maintained for about 2½ hours. The zinc solution is then drawn off and replaced by a tannin solution, a pressure of 100 lbs. being then maintained for about 1 hour. The tannin combines with the glue and forms a leathery waterproof substance which permanently closes the outer pores or cells, excluding the damp and retaining the zinc. The plant of the Atchison, Topeka & Santa Fe Ry. at Las Vegas, N. Mex. ("Engineering News," New York, Sept. 13, 1894), has two treating cylinders 6 ft. diameter and 106 ft. long. The hewed ties of native or mountain timber are here sawed to standard length and have the faces scarfed by a spotting

machine to give an even seat for the rails. The cost is about 10 to 15 cts. per tie, or 16 to 20 cts., including interest and repairs to plant. Ties treated by this process are said to give the best results in clay upland soil. The process has been applied to about 3,700,000 ties of mountain pine, hemlock and tamarack for the Union Pacific Ry., the Chicago, Rock Island & Pacific Ry., and the Atchison, Topeka & Santa Fe Ry. and from 91 to 96% have been in good condition after 7 years' service, treated hemlock sometimes outlasting untreated oak ties, owing to the hardening effect of the treatment reducing the wear from the rails. With green hemlock or beech ties at 35 cts. each, a treated tie would cost about 53 cts., and would have a life of 12 to 15 years.

In the zinc-creosote process, the ties are first treated with dead oil and then with a zinc solution, the latter passing through the oil into the denser parts of the tie, while the oil excludes moisture and retains the zinc.

Kyanizing.—This process consists in steeping the ties in a solution of about 1 part of bichloride of mercury (corrosive sublimate) to 100 parts, by weight, of water (or 1 lb. to 8 or 10 gallons), for about one day for each inch of thickness. Care is necessary in the operation, as the material is an active poison. It hardens the wood, but is generally found more satisfactory for timber in dry situations than for ties in the ballast and kept moist. The Boston & Maine Ry. used kyanized hemlock ties at one time, and found that the process paid when it was well done.

Thilmany.—In this process the ties are first impregnated with a solution of sulphate of copper (or sulphate of zinc) under 80 to 100 lbs. pressure, and then with a solution of chloride of barium, the two solutions forming a chemical combination of insoluble sulphate of baryta and chloride of copper (or zinc). It has not been much used for ties. Tests made by Mr. A. M. Wellington on the New York, Pennsylvania & Ohio Ry., in 1880, showed a decided loss of strength in the treated wood.

Boucherie.—In this process a solution of 1 lb. of sulphate of copper to 100 lbs. of water is applied, either in a cylinder, or by means of a cap fitted to one end of a log or tie, the solution being forced through by pressure or vacuum. It requires about 80 to 100 hours for the solution to travel through a log the length of a tie. The metal of rails and spikes is found to decompose the solution, producing free sulphuric acid, which attacks the fiber and weakens the timber.

Vulcanizing.—This is an American process which has been introduced within the last few years, and differs from those above described in that no impregnating material is used. The timber is placed in a closed cylinder and subjected to an air pressure of 100 to 175 lbs. per sq. in. at a temperature of 300 to 500° F. It is claimed that by this treatment the sap may be chemically changed to form a preservative composition, but it is stated on good authority that there is no knowledge of the physiology or chemistry of wood to sustain the claim of such changes. Tests of treated and untreated material of comparable condition, made by the Forestry Division of the U. S. Department of Agriculture, did not show any increase in strength, as claimed, nor any chemical or physical changes. It may be characterized as a development of a seasoning process, and with resinous woods may effect a more complete distribution of the resinous matter, which is in itself of a preservative character. Vulcanized Southern pine is used for ties, guard rails, guard timbers, station plat-

forms, etc., on the New York elevated railway. The cost is about 25 cts. per tie for ties 6 x 8 ins., 8 ft. long.

Miscellaneous.—Fernoline, spirittine and pinoline are preparations somewhat similar to wood creosote oil, and are used either as a bath for ties and timber, or as a paint for bridge and station timbers, joints of car timbers, piling, planking, and for ferryboats and scows, etc., to prevent decay and the attacks of boring worms. The Pennsylvania Ry. specifications for wood preservatives for such purposes require 5% tarry matter (not over 12%), 45% of tar acids (not less than 30%), and 50% neutral oils, a flashing point of 172 to 200° F., burning point of 200 to 220° F., running point of 15 to 20° F., and specific gravity 1.03 to 1.05. Carbolineum and Finch's preservative are applied to planking, ties, timbers, etc., by soaking or by brushing. Carbolineum should be heated to about 250° or 300° F., especially for wet or unseasoned timber, and the timber should be given two good coats, allowing 24 hours between the times of applying the coats and between the times of applying the last coat and using the timber. Woodiline is another composition, composed largely of wood creosote; it is used hot as a bath for ties, and used also as a paint. The Pennsylvania Ry. has used this, heating the ties and then placing them in the cold solution in an open tank 35 ft. long, 5 ft. wide and 6 ft. deep, the ties being handled by derricks. An oak tie will absorb about 1½ gallons after an immersion of three hours, but the average time of immersion is 12 minutes, giving an absorption of ½ gallon. The cost is about 15 to 19 cts. per tie, including material and labor.

When piles (whether treated or untreated) are left with the heads exposed, as in the case of fender piles, the heads should be coated with tar, which is better than creosote oil, since it forms a mechanical cover to exclude the moisture. If the heads of creosoted piles are tenoned for caps, the tenon and seat may be well painted with creosote oil. For filling old spike holes, tar or the cheap resin refuse from turpentine distilleries are better than wooden plugs or sand, and the resin is a good material for painting the ends of ties, where decay first occurs. Trackmen sometimes object to carrying the tar, but it is such an excellent material for this purpose that its use might well be made more general.

Metal Tie-Plates.

As already noticed, there is usually considerable trouble from the cutting of the ties by the rails, due to the local rot under the rail, and the wear and disintegration of the softened wood by the motion of the rail. This is especially the case with soft ties. The cutting also decreases the hold of the spikes by letting the rail drop loose below the spike head, and by causing rot around the spike holes, allowing the rail to get out of gage and to tilt on curves. The direct pressure of the rail on the tie has no effect beyond a very slight compression of the wood, but the cutting and wearing are due to the slight motion of the rail, which grinds and abrades the fibers and greatly facilitates local rot and softening, which in turn hastens the cutting effect.

One of the most important and practical of modern improvements in railway track has been effected by the wide introduction of metal tie-plates, which are placed between the rail and the tie, and which involve only a small first cost, but effect a most decided economy in ties and in track work. They may be considered in connection with preserved ties

and improved rail fastenings. Their cheapness, combined with their undoubted advantages in efficiency and economy, has led to their adoption on many hundreds of miles of track, as it is recognized that they not only increase the life of soft (and cheap) though durable untreated ties, but effect a direct economy in renewals and maintenance of way; while at the same time they add to the permanence and security of the track, by giving a uniform and durable bearing to the rails and lessening the disturbance of the track for tie renewals. They are especially advantageous for soft ties under heavy traffic. They also prevent the widening of the gage which occurs (particularly on curves) by the tilting of the rail, resulting from the lateral pressure causing the outer edge of the rail-base to cut into the wood. Tie-plates cause the spikes on both sides of the rail to act equally to resist lateral pressure in either direction, as the plate ties the two spikes together if the holes are made to fit the spikes (as they should be), and they reduce the wear or necking of the spikes by the edge of the rail, especially if the plate has an outer rib or lug to take the thrust of the rail. On curves the tieing together of the spikes is equivalent to double spiking, thus making the two spikes as efficient as three. On steep grades they prevent the increased cutting of the ties due to sand from the engines getting under the rail and acting to abrade the wood.

While the tie-plate is a decidedly modern invention it has already fully borne out the ideas of its designers and is now very extensively used, while its application is spreading very rapidly. Briefly this device consists of a metal plate interposed between the rail and the wooden tie, its purpose being to protect the wood of the tie from the cutting and abrading action of the rail, which action is more influential than any other in causing the destruction of the tie and rendering tie renewals necessary. The tie-plate is thus a species of tie preservative or protector, and is not to be classed with the old chairs and joint chairs whose office was to support the rail and hold it in position. It would seem at first glance as though such a simple thing as a tie-plate would not require much designing, and would not call for much theoretical consideration of the forces it has to sustain, but as a matter of fact, while the tie-plate is a small and simple thing enough in itself yet its efficiency may be very greatly increased by a little care in designing it with due regard to the work it is required to do. Almost any form of plate is an improvement over the direct contact between rail and tie, but it may readily be seen that there are opportunities for increasing the practical efficiency of the plates.

When first introduced it was predicted that they would make it more difficult to maintain the track to gage, but the very opposite has been the result, as they not only prevent the tilting or overturning motion of the rails, but also hold the inner and outer spikes together so that they both act to resist any forcing outward of the rail. On curves they have been successfully used in place of rail braces for the above reasons, as the great trouble (especially on sharp curves at switches and turnouts) is the tendency to overturn the rail on the outer edge of its base. When put on old ties a flat seat must be adzed for the plate, or the ties may be turned, as is the practice on the Southern Pacific Ry. If this is not done the plate will buckle and give an irregular support to the rail. In some exceptional cases where they have been put on old ties a saving of 50 to

75% in track work for maintaining gage, etc., has resulted. They should be large enough to give a good bearing on the tie, with room for the spike holes, and thick enough or stiff enough to prevent buckling or bending. If too large they may hold water under them and are more liable to buckle, while a very wide plate will not accommodate itself to the wave motion of the rail. Experiments with a bearing the full width of the tie showed that this caused the tie to rock in the ballast.

Tie-plates may be used with special advantage as follows: (1), At terminal yards, where, on account of frequent switching and the use of sand, the rail base cuts into the ties very soon, while their renewals are expensive in labor and interfere with the traffic; (2), at bridges, where the first cost of the ties and plates, and the cost of renewals, warrant the use of tie-plates; (3), on sharp curves, to save the uneven wear of the rails and the loss of thickness in the ties by frequent adzing of the rail seats, also to save the frequent respiking, and to maintain the correct gage and alinement to ensure an easy riding curve; (4), at switch leads on main track, under the rails that cut into the long ties, thus saving expensive renewals of ties otherwise perfectly good; (5), at rail joints on tangents (especially on three-tie or supported joints) to hold up the rail ends and prevent them from deflecting by cutting into the tie; (6), on tangents where ties are cut out by the rails before they decay. The plates may be used on every tie on bridges, trestles, curves, etc., and on tangents where soft ties are used, but with good ties they are sometimes used only at joints and quarter ties, or 6 to 10 plates to each rail. It is best, however, to use them on all ties, thus giving the rail a more uniform bearing. The use of tie-plates not only effects an improvement in the track, but also (at very little expenditure) effects a reduction in the expenses of track maintenance, since it enables soft and cheap durable timbers to be used for ties, as the timber is protected from the cutting action of the rail, and such cheap ties thus protected may actually last longer (and be thus more economical) than more expensive hard woods not thus protected.

The main objection to a simple flat plate is that it is impossible to keep it tight, so that there will be a continual movement of the rail on the plate and the plate on the tie, with a consequent admission of dust and moisture to cause wear and decay, and also a consequent clattering under traffic. Besides this, if the plate is thin and wide it will bend and buckle, while if made sufficiently thick to resist bending the plate will be clumsy and expensive. The question then is, how to secure a permanent connection between the plate and the tie, and this appears to have been most efficiently attained by making a plate with longitudinal ribs or flanges which sink into the fibers of the wood and are tightly held by them, while the size of the flanges is not such as to crush or split the wood. These flanges also serve to stiffen the plate and enable a thin plate to be used without buckling under heavy loads.

Flat-Bottom and Flanged Tie-Plates.—Thin flat plates were first used, but these were apt to buckle and crack, and being comparatively loose on the tie, they held the water and churned it into the tie, causing local rot, while the loosening of the ordinary spike fastenings led to a disagreeable clattering under the trains. The New York elevated railways laid some flat plates 6 × 8 ins., ¼-in. thick, in 1888, but in addition to buckling and cracking at the ends, they induced premature decay of the wood (yellow

pine) under them. They jumped and rattled under passing trains, and thus in wet weather forced the water into the wood, and kept it wet, thus hastening rot, especially in summer when the tie-plates were hot and the ties damp. Yellow pine ties which had been less than 6 years in the track had to be removed in 1894 because of the decay due to the effects of moisture under these flat-bottomed tie-plates. In some ties the rot extended to the sap wood beyond the plates, while in heart wood it was confined to the part covered by the plates. The ties removed were in varying stages of decay. As a result of this experience, flanged plates were adopted and are now extensively used on these lines. In order to unite the plate firmly to the tie, various arrangements of teeth, spurs and flanges on the bottom of the plate have been tried. These should be so designed as to do as little damage as possible to the surface of the tie, while securing a firm hold in the wood, so as to make the plate act absolutely as a part of the tie. It is almost impossible to make a flat-bottom plate as efficient as one which has a hold in the tie independent of the rail fastenings, especially if no more secure fastening than the ordinary spike is used. Nevertheless the Pennsylvania Ry. prefers a flat-bottom plate, from a belief that flanges will cause cracks in the wood.

Bottom Flanges and Teeth.—In respect to the methods by which the plates are attached to the ties, the plates may be divided into two classes: (1), Those in which the projections are lengthwise with the tie and approximately parallel with the fibers; (2), those in which the projections are transverse to the tie and cut across the fibers. The long experience with the flanged plate of the first class, having longitudinal flanges sunk into the tie, appears to have substantiated the claims made for it, both in security of grip and in protection of the wood of the tie; while the objection that the flanges will cause checking and cracking and afford chances for rot to set in does not seem to be sustained. For the Goldie plate, with four chisel-edged claws or spurs cutting across the grain, it is claimed that the grip is equal to that of four good spikes, and that any lateral motion of the plate is absolutely prevented, while the sharp edges and narrow faces of the spurs prevent serious injury or crushing of the fibers. To this it is objected that outward thrust on the plate will force out the fibers cut by the spur, but this does not seem probable, except, perhaps, in very soft and poor ties. For the Churchward plate, with two rows of beveled teeth or lugs on the underside, cutting across the grain, it is claimed that these lugs wedge or compress the fibers so as to close tightly against the lugs, thus preventing any cracking or entrance of water, but it seems to be doubtful whether this method will give a good hold upon the tie. An objection made to plates of the second class is that it is difficult to drive the projections in so that the bottom of the plate will have a perfect bearing on the tie, the result being that many plates break under wheel loads. It is certain that a tie-plate must in some way be self-attached to the tie, so that it will not move under the traffic, but it appears doubtful whether any provision to prevent such a plate from moving lengthwise on the tie is necessary. In any case, the plate should be properly bedded upon the tie in the first place, and not left for the traffic to drive it home, as the traffic will not do this efficiently, and meanwhile there is a liability of gravel, ballast, etc., getting under the plate.

Rib and Flat-Top.—For plates having ribs on top to engage with the

outer edge of the rail base it is claimed that one of the important functions of the tie-plate is to relieve the spike from the outward thrust of the rail and the wear due to abrasion by the edge of the rail base, leaving it to merely hold the rail down upon the plate. This certainly seems reasonable, especially when we consider how inefficient the spike is in itself as a fastening for rails carrying heavy traffic. When once the compression of the wood of the tie or the vertical motion of the rail have given ever so slight a play between the rail base and the spike head, then the abrasion of the neck of the spike will at once commence. In such a case, if the tie-plate has a rib the abrasion will be distributed over the whole length of the rib, instead of being concentrated on the narrow neck of the spike. On the other hand, it is claimed that the Servis flat-top plate (which has been used more extensively and for a longer time than any other plate in this country) has been found entirely satisfactory in this respect, and that little or no "necking" of the spikes had been found, even on sharp curves, provided that the rail base is the full width between the spike holes of the plate and that old "necked" spikes are not redriven with the plate. In other words, there has been no trouble where full contact and an absence of play are insured in the first place, as, of course, they should be in good tracklaying. As some railways, however, were found to have decided opinions in favor of a rib, the makers designed a plate of this form, but differing radically from others by having the rib at right angles to the rail, and cut away for the width of the rail base. The claim made for this plate (which the makers do not consider superior to the flat-top plate) is that any outward movement of the rail at one point must be accompanied by a corresponding inward movement at another, and that therefore if it is necessary to hold the rail at all, it must be held on both sides to get the best results.

Width of Plates.—Narrow plates are sometimes advocated, to concentrate the load near the middle of the tie and thus approximate to an ideal bearing, narrow at the top and wide at the bottom. It is stated that in actual service some plates 3¾ ins. wide have given better results than others of the same make 6 ins. wide; and that 6-in. plates have even been abandoned in favor of 5-in. plates. The rocking of very wide ties is cited in this connection. On the other hand, it is claimed that narrow plates increase the distance between the rail supports, thus reducing the stiffness of the track. The disadvantages of increasing the span, especially with light rails, are very evident, and it is a question whether a greater number of narrower ties might not be used to advantage with the narrow plates, giving a closer bearing for the rail with an equal bearing in the ballast.

Thickness of Plates.—For thin plates it is claimed that the thinner the plate can be made (as long as it is able to resist buckling), the better it will be, as it will give a more perfect union with the tie than a thick plate. In the Servis plate, which is stiffened against buckling by its longitudinal bottom flanges, the thickness is 3-16-in., which has been found satisfactory, provided, of course, the plates are properly put on, so as to have a uniform bearing. As neither the Goldie nor Churchward plates have this stiffened shape, they must rely on the thickness of the plate to prevent buckling, and for the latter a thickness of ½-in. is recommended, while the former is made ¼-in. and ⅜-in. (the latter being recommended). As to the wear of the plate by the rail, experience shows that this is very

slight, so that great thickness is not required to resist such wear, and a thin plate, which will not buckle and will not work under the traffic so as to injure the tie, would therefore appear to be as efficient as, and more economical than, a thick and heavy plate.

Shimming.—A question very often asked in regard to the use of tie-plates is as to the method of shimming on ties so equipped. Considering the difficulty of removing a well-seated flange plate, and the injury resulting to the tie, as well as the impossibility of getting the plate as well fixed again after the shimming has been withdrawn, the shims should be placed between the plate and the rail, being bored to correspond with the spike holes in the plates. Where shims more than 1½ ins. thick are required, a piece of plank should be spiked to the tie, and the shims placed upon it; while if the traffic is very heavy, a second tie-plate may be placed on top of the shims. The tie-plate is intended to be a permanent part of the track, and should never be removed to allow for the temporary expedient of shimming, unless, of course, a flat-bottom plate is used.

The Southern Pacific Ry. uses on its Pacific Coast lines redwood ties, which are very durable, but soft, and to avoid the cutting of the wood a

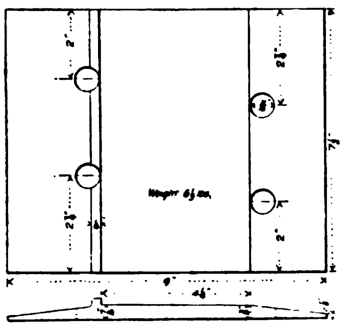


Fig. 15.—Flat Tie-Plate; Southern Pacific Ry

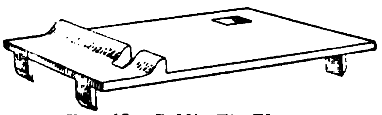


Fig. 18.—Goldie Tie-Plate.

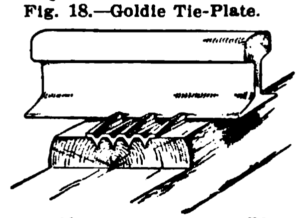


Fig. 19.—Wolhaupter Tie-Plate.

flat wrought-iron tie-plate was designed, as shown in Fig. 15. The plate is 9 × 7½ ins., ⅜ to 7-16-in. thick under the rail, and weighs 6⅛ lbs. It will be noted that the rail seat is inclined, which is an uncommon practice in this country, though almost universal in foreign countries. There are four round holes for the screw spikes, and a rib receives the outward thrust of the rail base. With ordinary spikes in this soft wood it has been found difficult to hold the rail firmly to the tie, and the play between rail and tie contributes very largely to the cutting and wearing of the timber. It was thought that flanges might split the ties, but flanged plates have now been used with success.

The Servis tie-plate, now in very extensive use, is 3¾ × 8 ins., with two flanges on the under side, or 5 × 8 and 6 × 9 ins., with three flanges about ¾-in. deep. It is 3-16-in. thick. Wide plates are used on soft ties under heavy traffic, where extra spiking is required (as on sharp curves and heavy grades), and at supported joints. The New York Central Ry. uses a plate 6 × 9¾ ins. and 13-16-in. deep over all on the middle tie of its three-tie joint. The flanges are parallel with the length of the tie, biting into the wood and compressing the fibers between them, so that the plate is held very firmly to the tie, and there is no rattling. Oak ties on a grade of

1.5% on the Pittsburg, Cincinnati, Chicago & St. Louis Ry. bridge over the Ohio River at Louisville, Ky., were marked for removal after 6 years' service on account of the cutting in of the rails. As the ties were sound it was concluded to try the Servis tie-plates, and during 4 years' use of these plates no work was done on the track, while formerly three men were almost continually employed in shimming, lining, gaging, and redriving spikes. In 1893 a number of the ties were found to be rotting away beyond the plates, but the plates were still affording ample support to the rail, showing clearly the compressing of the fibers between the flanges so as to exclude moisture. The traffic amounted to 150 trains per day. On this and other bridges, and on some 6° curves, the saving due to the use of the plates is estimated at 50% in ties and 60 to 75% in labor. In laying these plates, the line side of the tie is marked, and the plate put on, the other plate being then put on in its proper position by gaging it

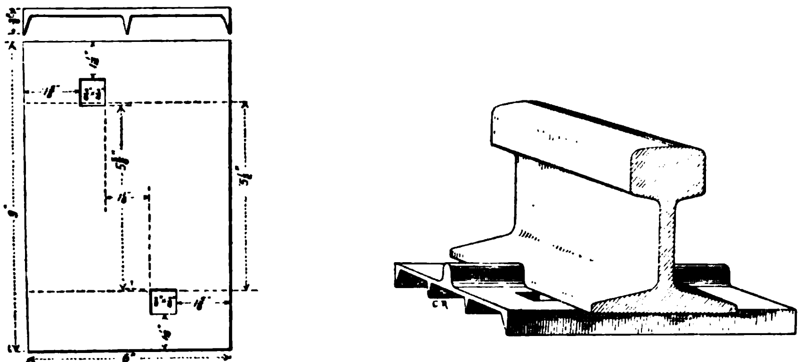


Fig. 16.—Servis Tie-Plates.

from the line plate with a gage-rod having lugs to fit the spike holes. The plates may be forced into the tie by a hydraulic press, or in the track by striking vertically with a paver's rammer. In some cases the plate is hammered with a heavy wooden sledge to make the flanges bite into the tie, but this is very objectionable as a careless man will bring the edge of the sledge down on the middle of the plate, bending it so that the rail will rest only on the two edges of the plate. In putting plates on before the rails are laid, a wooden or metal block should be placed on the plate to distribute the force of the blow. If put on after the rails are laid, the rail may be lifted, the plate slipped in, an iron plate placed upon each projecting end of the plate, and these two plates struck simultaneously by two spikers with spike mauls. One end of the plate may be settled into the tie, and the free end then driven with a sledge, causing the flanges to plow their way through the wood under the rail. The ordinary form of plate is flat-topped, as shown in Fig. 16, but it is also made with a transverse rib on the upper side, the rib being cut away for the width of the rail base. The reasons for this latter form have already been stated. These plates are made by the Q. & C. Co., of Chicago.

The Churchward tie-plate, Fig. 17, has on the upper side a rib to take the thrust of the rail flange, and on the lower side 6 blunt teeth of V-section, which cut across the fibers. The plate is of rolled steel, and has at first two ribs on the under side, which are formed into teeth by passing

the plate through rolls having pockets instead of grooves. The teeth are about 1 in. long and ⅜-in. high, while the upper rib is ¼-in. high. The plate is 8 or 9 ins. long (lengthwise of the tie), 6 ins. wide, ½-in thick, and weighs 4 lbs. The teeth are shorter on the edge than on the base, in order to wedge themselves into the wood, and it is claimed that no water can get in, especially when the plate rests flat on the tie. (The Johnson Co., Lorain, O.)

The Goldie tie-plate, Fig. 18, is of rolled steel, 8½ ins. long, 4 to 6 ins. wide, and ¼ to ⅝-in. thick. It has a rib on top, parallel with the rail, and has at each corner a flat, chisel-edged lug, which is driven into the tie, cutting across the grain. Another form has two ribs of V-section on the under side, cutting across the fibers, the ribs being the full width of the plate, and it is claimed that water cannot get in around them. (Dilworth & Porter, Pittsburg, Pa.)

The Wolhaupter tie-plate, Fig. 19, is rolled with a number of longitudinal ridges, forming flanges which bite into the tie, practically parallel with the fibers, while the channels or spaces between the bearing surfaces receive any sand or gravel which might otherwise work under the rail. The spaces between the lower flanges are of arch form, so as to compress the fibers. Lugs or shoulders on the outer side of the plate resist the thrust of the rail. (Railway Supply Co., Chicago, Ill.)

Tie-plates of various forms have been extensively used in foreign countries, and are generally made heavier than those used in this country. As a rule these plates are flat-bottomed, some few having teeth, and others a rib fitting into a notch cut across the tie. The cutting of ties in this way, or to let thick tie-plates in flush with the top of the tie, is a bad practice. The difficulty arising from the looseness of flat plates is in

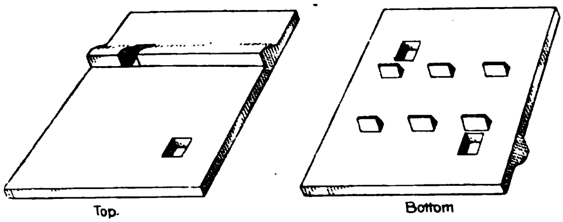


Fig. 17.—C. A. C. Tie-Plate.

part overcome by secure fastenings in the way of screw spikes, bolts, etc. Compression of the wood under the plate makes it necessary at first to occasionally tighten up the fastenings, but the compression is slight and does not continue, so that when once firmly settled the fastenings require but little attention.

The Sandberg tie-plate, Fig. 20, designed by Mr. C. P. Sandberg, the European rail expert, is about 12 × 18 ins., ½-in. thick, and weighs about 13 lbs. It is fastened to the ties by fang bolts, screw spikes or common spikes, and has lugs on the upper side to engage the rail flanges, the rails being secured by taper steel keys driven horizontally between the rail and lugs. He has recognized that the cast-iron chair is the weak point of English railway tracks, and has shown that with flange rails and tie-plates a track can be built more economical than and equally as strong as the track with bull-head rails and chairs. This is the view

which the author has frequently expressed. Unfortunately the conservative objection to tie-plates in Europe has led Mr. Sandberg to suggest a very broad rail base, which is not to be commended. The tie-plate designed by Mr. J. W. Post, of the Netherlands State Railways (inventor of the well-known Post steel tie) is of the heavy type usually adopted in European railway practice, and is used with clamps and screw spikes for rail fastenings, Fig. 21. It is made with the bottom flat and also with sharp teeth on the bottom, the teeth being about 3-16-in. deep, but if the tie has a knot or hard place at the seat for the plate, the flat-bottomed plate is the better, as the toothed plate sometimes gives an irregular gage under the circumstances. The steel tie-plate of this type now used on the Netherlands State Railways is flat bottomed (except that the maker's mark is in raised letters on the bottom), but is otherwise similar to the form illustrated. It is 8.56 ins. wide and 8 ins. long, 0.52 to 0.74-in. thick at the rail seat, which is 4.32 ins. wide, inclined 1 in 20. The outer edge of the rail butts against the edge of the rail seat, and is held by a screw spike whose head bears directly upon the rail and the side of the tie-plate. The inner edge is held by a clamp and a similar spike. The plate has 3 spike holes 0.96 to 1 in. diameter along each side. The spikes are

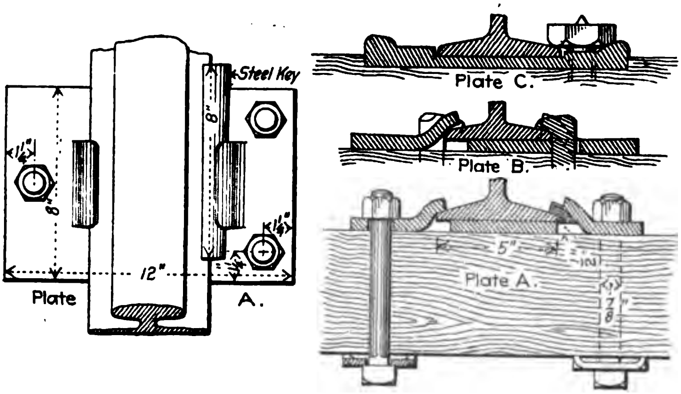


Fig. 20.—Sandberg's Tie-Plates.

7.5 ins. long over all, 5.56 ins. long under the head, 0.57-in. diameter in the shank, and 0.89-in. diameter over the threads, which have a pitch of 0.48-in. The spike head is 2 ins. diameter, with a tapering projection, 0.84 to 0.92-in. square, for the socket of the track wrench. The standard track of the Prussian State Railways consists of 82.65-lb. T-rails, resting on flat-bottomed steel tie-plates 7½ x 6½ ins. and ½ to 11-16-in. thick under the rail. Each plate weighs 8.82 lbs. The top surface is grooved to fit the rail flange, and the rail seat is inclined. Three screw spikes are used.

Metal Ties.

The question of the use of metal ties as a substitute for wooden ties cannot be passed over, for while the use of such ties is not likely to obtain in this country for many years, yet it is very probable that they will ultimately be generally adopted. This will not be until after the era of preserved wooden ties, metal tie-plates and improved rail fastenings

has become very much further advanced, and, in fact, what is needed now is a thorough improvement of existing track, with improved maintenance. Metal ties have passed beyond the experimental stage, and are very largely used in foreign countries, both for pioneer and local railways, and for main lines with heavy traffic. The author's reports on "The Use of Metal Ties for Railways" (issued by the Forestry Division of the United States Government in 1890 and 1894) showed that there were 25,000 miles of metal track in 1890, and 35,000 miles in 1894, or 13 and 17½% respectively, of the total railway mileage of the world. This is exclusive of the United States and Canada, since metal ties are used to but an infinitesimal extent in the former, and not at all in the latter.

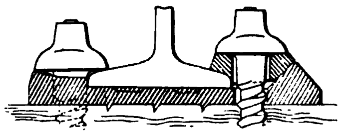


Fig. 21.—Post's Tie-Plate; Netherlands State Railways.

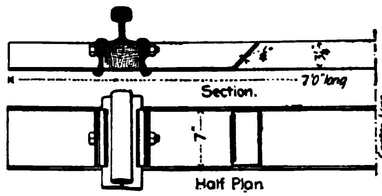


Fig. 23.—Standard Steel Tie.

The advantages of metal ties are in greater length of life, reduced cost and labor of maintenance, superiority of track, permanence of roadbed due to reduction in renewals and maintenance, and consequently a decided ultimate economy. It has been argued that a good track cannot be maintained with metal ties, and that the track will be noisy and uncomfortable. These objections cannot be sustained in view of the generally satisfactory and successful results obtained as to the points noted above in long and extensive experience in other countries, under all conditions of climate and traffic. On the other hand, some enthusiasts claim that no track can be good, secure and economical without metal ties, and that any form of metal tie is superior to a wooden tie. Such claims are, of course, impractical and absurd, since of the innumerable forms of metal ties which have been tried a comparatively small number

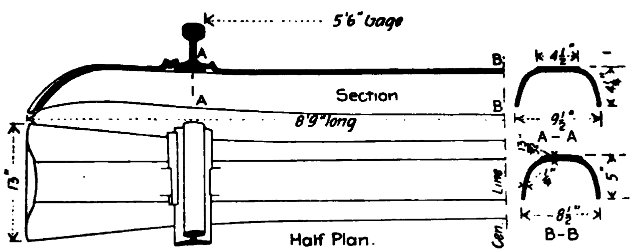


Fig. 22.—Rendel Steel Tie; Indian State Railways.

has proved successful. In India, 80-ton engines with 1,000-ton freight trains and express passenger trains have for years been running over metal ties, and not only are the maintenance charges for labor and material very low, but the track is as good and as smooth as that laid with wooden ties. A part of the Netherlands State Railways (Holland), laid with Post steel ties, and carrying 25 trains daily, was carefully tamped

and put in condition, and was then left for 40 months without any other work than occasional tightening of the nuts. The life will vary from 20 to 40 years, and even 50 years is claimed. For the first 2 to 4 years, the labor and cost of maintenance will be in general as much as, if not more than, with wooden ties, the expense being mainly on the ballast and rail fastenings, but the track then becomes well consolidated and the attention required steadily decreases; while with the wooden ties it increases year by year, until renewals are necessary. One of the great advantages of metal track is that it is not disturbed frequently for tie renewals, and is thus kept in good condition for running.

The fastenings should be of as few parts as possible, and invariably interchangeable, not requiring special parts for curves, joints, etc. The simple key fastening of the Rendel tie, making only two pieces besides the tie itself, are very satisfactory, and some of the bolted clamp fastenings of European ties are found to remain tight and prevent rattling. The bolted clamp of the New York Central Ry. allows of an adjustment of gage at curves, switches, etc. To prevent noise due to the contact between steel rail and steel tie, packings of felt, wood, asbestos, tarred canvas, etc., have been tried, but without much success. With good fastenings, that do not work loose, there is little need of any such packing between the metal surfaces. The use of wooden bearing blocks on metal ties is not necessary and not to be recommended, as it is decidedly better to firmly attach the rail direct to the rail seat of the tie or else

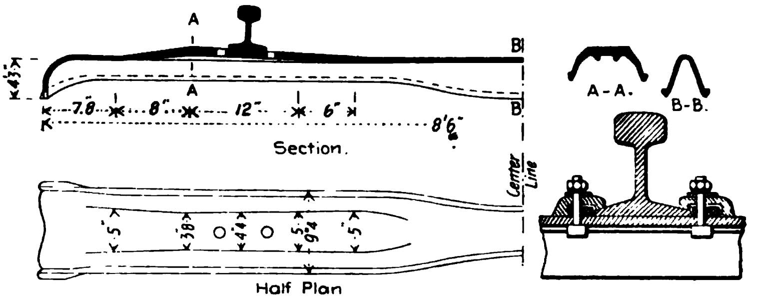


Fig. 23.—Post's Steel Tie.

to use a metal tie-plate. The ends of the tie should be closed, so as to give at least the same end area as that of a wooden tie to resist lateral motion in the ballast, while the friction of the enclosed core of ballast over the other ballast greatly increases this resistance. Broken stone ballast, 1 to 2 ins. in size, is the best material for main tracks. With metal track, wooden ties are very generally used at frogs and switches, but steel ties can be (and are) used, affording extra security.

Cast-iron bowls and plates connected in pairs by transverse tie-rods are extensively and successfully used in India and South America, but this material is not to be recommended for use here. Its only application in this country has been at the Grand Central Station of the New York Central Ry. in New York, where Toucey's cast-iron boxes were used, having wooden blocks to which the rails were secured by Bush interlocking bolts. The most approved type of tie, and that which by the survival of the

fittest is now the most used in modern practice, is a steel (rolled or pressed) cross tie of channel or trough section, with ends closed, and laid inverted in the ballast. This is developed from the type of tie invented by Vautherin, the French engineer, and first used more than 30 years ago.

The manufacture of the tie itself and of the fastenings should be carried out with such care as to ensure good material and accuracy of fit and gage. Bessemer, Thomas and Siemens-Martin steel is used, having about 0.1 to 0.2% of carbon, and of such quality as to have a tensile strength of 50,000 to 60,000 lbs. per sq. in., with an elongation of 18 to 20% in 8 ins., and a reduction in area of 30 to 40% at point of fracture. The steel of the New York Central Ry. ties has 0.1% carbon, 0.4% manganese, 0.081% phosphorus and 0.033% sulphur. It is made thus soft to stand pressing to shape. Corrosion occurs in certain saline and other soils, and the ties are usually dipped hot in a tar bath. The Hartford ties of the New York Central Ry. were treated with the Angus-Smith solution, as used for water pipes, applied at a temperature of 300° F. Cracks are less likely to start with drilled than with punched bolt holes. The tie should be of as simple design as possible, and with the smallest number of parts consistent with security and the necessary adjustments; of sufficient thick-

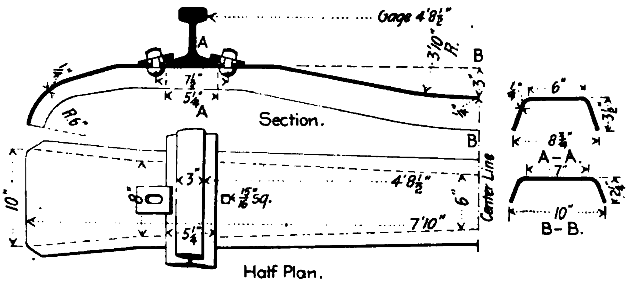


Fig. 24.—Hartford's Steel Tie; New York Central Ry.

ness for wear and strength, and of sufficient weight to hold the track down well. From 100 to 120 lbs. is probably the best weight for a tie for first-class track and heavy traffic. The weight may be increased by covering the tie with ballast. In France, steel ties damaged by derailed cars have been straightened out and put back in the track, while one of the railways in India, using the Rendel steel tie, Fig. 22, has put in a hydraulic press for reshaping any ties bent or distorted by such accidents.

The Rendel steel tie, Fig. 22, which is extensively used in India, is 8 ft. 9 ins. long for tracks of 5 ft. 6 ins. gage, and from 8½ to 13 ins. in width, while the thickness is 13-32-in. for a width of 4½ ins. on top, and ¼ in. on the sides. At the rail seat it is 9½ ins. wide on the bottom, 4½ ins. deep; and at the middle, 8½ to 9 ins. wide and 4⅞ ins. deep. Four lugs are stamped up out of the top, and flat taper keys are driven between the outer lugs and the rail base. The tie weighs 120 lbs., and the two keys 1 lb. each. The ties are laid about 3 ft. c. to c. The Post tie, Fig. 23, is the invention of Mr. J. W. Post, Engineer of Maintenance of Way of the Netherlands State Railways. It is of varying section, being thinner, narrower and deeper at the middle than at the ends, thus securing ample strength with an economical distribution of the metal. For standard gage lines it is 8 ft. 4 ins. to 8 ft. 9 ins. long, weighing 117¾ to 120 lbs.

The thickness on top is 0.48 to 0.52 in. at the rail seat, decreasing to 0.24 in. at the middle; on the sides the thickness is from 0.24 to 0.36 in. At the middle the tie is 4½ ins. deep, 5½ ins. wide over the bottom, with side slopes of 1 to 3. At the rail seats it is flat for 4½ ins. on top, 10¼ ins. wide over the bottom, and 3 ins. deep. The bolt holes are 1 × 1¼ ins., oblong, with rounded corners (to prevent cracks); and the bolts are ⅞-in. diameter, with hexagon nuts 1⅛ ins. thick. The joint or shoulder ties are laid 2 ft. apart, and the intermediate ties 3 ft. apart.

The New York Central Ry. has had 800 of the A. J. Hartford steel ties in service near Garrisons, N. Y., since 1889, and in 1894, after 5 years' service, the ties and their bolt fastenings were in excellent condition. As a result, this road had 18,000 ties made of the modified Hartford type, shown in Fig. 24, with the bolted clamp fastenings devised by Mr. Katte, the Chief Engineer, in which the clamps have a wedge grip on the rails. These ties were for use on the Park Ave. line approaching the Grand Central Station in New York, where the smoke and darkness in the tunnels and the constant traffic make maintenance and renewals difficult, expensive and dangerous. The ties are of pressed steel, and weigh about 100 lbs. each. The ties were not laid, however, for the reason that the adoption of the track circuit for the block signal system made it necessary to insulate the rails from the ties, involving an additional expense. The Standard steel tie, shown in Fig. 25, has been tried on the Chicago & Western Indiana Ry. and some other roads. It is of channel section, placed open side up, with the bottom cut loose and bent up in the middle of the tie to offer resistance to lateral motion. The ends of the tie are open and the tie is filled with ballast, but the core of ballast is separated from the body of the ballast. The rails rest on wooden blocks, and are secured by horizontal bolts through these blocks, as shown.

The Pennsylvania Ry. has tried some of the Webb rolled steel trough ties with riveted steel plate chairs (for bull-head rails), as used on the London & Northwestern Ry. of England, but the ends are open, and although covered with ballast, the ties shifted laterally, so that timbers have been put in between the ends of the steel ties and the ends of the wooden ties of the adjacent track. This road also tried some light but very expensive channel iron ties with riveted cross pieces and rail braces, involving considerable shop work. In 1892 statements were published to the effect that this road was abandoning metal ties after 15 years of experiment, and that metal ties had been proved a failure. These statements no doubt had some weight with persons not well informed as to the facts. As a matter of fact, the limited trials on that road were of too little significance for any such conclusions to be drawn, especially in the face of wide and successful experience in other countries. Of the numerous designs of metal ties patented in this country, only an almost infinitesimal proportion have any practical value, owing mainly to the failure of the inventor to comprehend or provide for practical conditions of service. Lightness and cheapness are too often aimed at as of first importance, or the design is too unwieldy and complicated to be of any use. It is almost useless to put in a few metal ties, but at least half a mile of track should be laid if any definite conclusions are desired.

CHAPTER 5.—RAILS.

History.—The development of the modern railway rail may be briefly summarized as follows: Flat cast-iron rails or plates, about 3 ft. long, were first used, and these were succeeded by cast-iron rails of L-section, laid with the horizontal flange outward, the ends of the rail resting on stone blocks. On these angle-rail tracks, flangeless wheels were used for the cars, which were generally coal cars. About 1789, "edge" rails were introduced, the wheel running on the upper edge of the rail and being guided by a flange on the wheel, instead of running on the bottom of the rail and being guided by a flange on the rail. The first were of cast iron, fish-bellied, in short lengths of about 3 ft., with the ends resting on stone blocks or in cast-iron chairs on these blocks. Later on, the rails were made of wrought-iron, in lengths of about 15 to 18 ft., fish-bellied between supports about 3 ft. apart. These rails were rolled, the rail and rolls being invented by John Birkinshaw, of England, in 1820. Scarfed joints were used with some of these rails. From 1820 to 1850 the flat strap-rail spiked to longitudinal timbers resting on cross ties was largely used in this country, as that was the only form that could be rolled here, edge rails being imported. Another form of section used on some of the early American railways, and also in Europe (generally on longitudinal timbers), was the bridge rail, designed in this country by Mr. Strickland in 1834, and in England by Mr. Brunel in 1835. This has generally been used in comparatively light and shallow sections, but has also been suggested as a good section for a heavy rail.

The present flange or T-rail section was invented in 1830 in this country by Col. Robert L. Stevens, Chief Engineer for the Camden & Amboy Ry., and the first order was placed in England by him for this road. He also designed the hook-headed spike and flat splice plate, which have de-

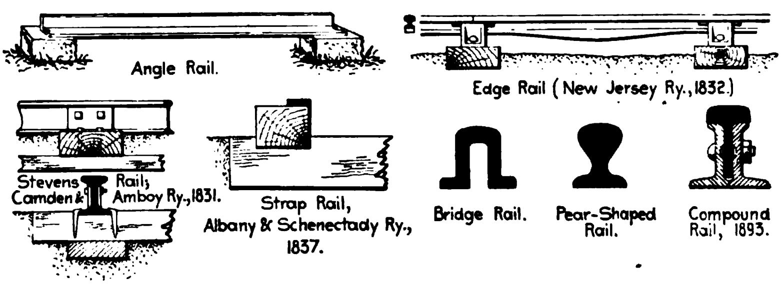


Fig. 26.—Old Forms of Rails.

veloped into the modern spike and fish plate and angle bar. In Europe, this rail is generally called the Vignoles rail, having been re-invented in England in 1836, by Mr. Charles Vignoles. The fish-plate joint was also re-invented in England by Mr. W. Bridges Adams, in 1847. English rolled rails were imported to this country in 1832 for the Portage Ry. and the New Jersey Ry. Cast-iron rails 6 ft. long were made in Pennsylvania in

1841. Rails were first rolled in this country in 1844, and these were of U or bridge section. Double-headed rails were also rolled here, as noted later. The Stevens rail was first rolled here in 1845. At first the T-rails were of very clumsy section, the pear-shaped head being very common, partly on account of the poor quality of the iron making it necessary to have a considerable support for the head, but with such a section no satisfactory fish-plate joint could be made, and the rail bases therefore fitted in iron shoes or chairs at the joints. The weight ranged from 40 to 65 lbs. per yd. The early rails above referred to are shown in Fig. 26.

Various forms of compound rails have been designed, particularly in the early days of railways, to enable the wearing part of the rail to be renewed, but the majority proved failures, owing either to faulty connections or too great complication. The idea has, however, been revived in connection with modern heavy track, and in 1894, Mr. Katte, Chief Engineer of the New York Central Ry., suggested the compound rail shown in Fig. 26.

Steel rails were first rolled in England about 1855. They were rolled experimentally in this country in 1865, and to order in 1867, when the introduction of the Bessemer process was the beginning of a great advance in the art of rail manufacture, with a great reduction in cost.

Development of the Modern Rail.—When railway development began again in 1865, after the close of the Civil War, more attention began to be paid to the design of rails, and in 1865 Mr. Ashbel Welch designed a T-rail whose proportions approximated to those of modern sections, but in which the English practice of that day was followed in using rounded sides to the head. His 62-lb. rail was 4½ ins. high, with a base 4 ins. wide. About 1874, Mr. R. H. Sayre designed a rail having a head with top corners of large radius and sides sloping outward from the top, with the idea of reducing the wear by the wheel flanges. The Sayre section, as adopted on the Lehigh Valley Ry. in 1883, had a flare of 10°, but in 1891, when a new 80-lb. section was adopted to replace the old 76-lb. section, part of the metal was added to the sides of the head, reducing the flare to 5°, which is retained in the new 90-lb. section of 1895, Fig. 27. The Fall Brook Ry., after some years of experience with the Sayre section, abandoned it for one with a wide thin head having vertical sides, but still retained the heavy Sayre splice bars. The rail of the Georges Creek & Cumberland Ry., however, went even beyond the Sayre section, having a flare of 20°, and this is still believed in on that road, for the reason that rails on sharp curves wear to that section, and that vertical sides wear the wheel flanges. It is now, however, almost universally recognized that the best results are obtained with rail heads having sharper top corners and vertical sides; and the typical Sayre section has been practically abandoned, though some designers still adhere to a slight flare of 4° or 5°, with the idea of keeping the wheel flanges away from the corner of the rail head. Rail sections with the sides of the head sloping inward from the top are used on some European railways, and the Providence & Worcester Ry. rail of 1885 had this form, but this feature of the design is decidedly bad. Between 1880 and 1888 there was a tendency to give a large corner radius (¾ to ⅞-in.) to the top of the head, to fit the fillet of the wheel tire; thus causing a considerable rubbing friction of the wheel flange on the rail head (aggravated in some cases

by outward flaring sides to the head) in addition to the normal rolling contact with the wheel tread.

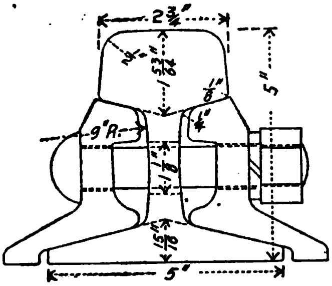
In 1873, the American Society of Civil Engineers appointed a committee to report upon the forms, sizes, manufacture, tests, endurance and breakage of rails and also the comparative economy of iron and steel rails. In 1883, another committee was appointed to consider the proper relation to each other of railway wheels and rails. This was in view of the disputed ideas as to these relations, it being asserted on the one hand that the car wheel tread and flange should have as long a line of contact with the head of the rail as possible, and, on the other hand, that such long contact would be dangerous and cause undue wear and friction. Those holding the former view favored a round upper corner to the head, fitting the fillet of the wheel; while the others favored a sharp corner, keeping the wheel flange away from the side of the rail head. This committee's investigation showed (1) that the number and disadvantages of sharp-flanged worn wheels had been greatly exaggerated; (2) that sharp corners did not produce this character of wheel wear to the extent claimed; and (3) that round-cornered rails showed greater side wear due to cutting by the wheel flange, while the rail wear became more rapid as soon as the side of the head began to be attacked; and (4) that rails often fail with little material abraded from the top by wear proper, being crushed after the flow of metal has reached its limit, and thus failing by rapid disintegration due to heavy wheel loads. The committee recommended a top radius of 12 ins., a broad head relatively to depth for sections of all weights, ¼-in. top corner and 1-16-in. bottom corner radius for the head, and vertical sides for the head (starting from a sufficient base width of head to give ample bearing for the joint).

This led to the appointment of a third committee to prepare designs for standard rail sections, in an endeavor to reduce the number of existing sections (as adopted at hap-hazard) to some standard of uniformity, so that rail mills would be able to roll to stock, instead of having to roll so many special sections. At that time there was an almost entire lack of uniformity in rail design, and the rail mills had to carry enormous stocks of rolls for the innumerable forms of sections. Many of these sections were practically identical, but had minute variations in certain dimensions, as the result of the whim of the designer or his ignorance of the existence of a practically similar section. Each engineer had his own ideas as to rail design and desired to have his own special form of section on his own line. At present, however, there is a strong tendency towards the adoption of uniform sections. This third committee made a very thorough investigation, and in 1893 presented its report (which was adopted), with recommended standard sections varying by 5 lbs. from 40 to 120 lbs. per yd. The metal was distributed as follows: Head, 42%; web, 21%; base, 37%. This type of section has been very generally adopted, and is shown in the 80-lb. rail, Fig. 28. In all these sections the height of rail and width of base are equal and all have the following constant dimensions:

Top of head	12 ins. radius.	Side of web	12 ins. radius.
Top corners of head	5-16-in. "	Top fillets of web........	¼-in. "
Bottom corners of head..	1-16-in. "	Bottom fillets of web....	¼-in. "
Corners of base	1-16-in. "	Fishing angles	13°

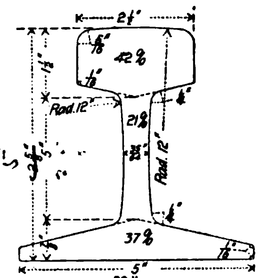
As to the form of section, it may be said, as the consensus of experience and investigation, that the head should be wide and thin, with sharp

top corners, and sides vertical or nearly vertical, and having fishing angles of not less than 13°. The web is sometimes made with curved and sometimes with vertical sides. The former, of course, gives no greater strength, but is claimed to give a better compression of the metal in the thick parts at the union of the web with the head and base. The edges of the base should not be too thin, and should be rounded in one curve of about 5-16-in., or with 1-16-in. top and bottom curves, the object of this being to reduce the cutting of the ties by the sharp edges. The width of base should be equal to, but not greater than, the height of the rail. If metal tie plates are used the width of base may be slightly less than the height.



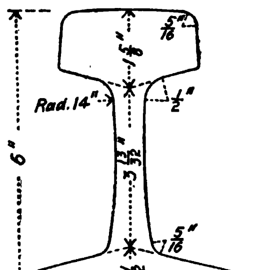
90 lbs.

Fig. 27.—Sayre Type; Lehigh Valley Ry.



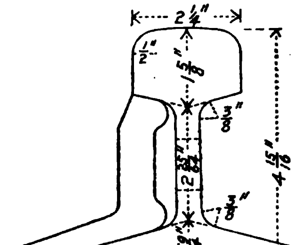
80 lbs.

Fig. 28.—Type of American Society of Civil Engineers.



100 lbs.

Fig. 29.—Dudley Type; New York Central Ry.



72 lbs.

Fig. 30.—Sandberg Type; Canadian Pacific Ry.

Tie-plates should be used with heavy traffic, as the attempt to get a very wide base support in the rail flange usually results in a section which is not adapted to good rolling. Flat-topped rail heads have been advocated, but the metal in the head does not get so much work or squeeze from the rolls, and is thus of less dense texture on top than is desirable. This was found with rails rolled in England 25 or 30 years ago for the New Orleans & Chattanooga Ry. In addition to this, the lateral play of the wheels would soon wear the top to a curved section. The usual top radius is 12 or 14 ins., though the Chicago, Milwaukee & St. Paul Ry. makes it 18 ins., and any radius less than 12 ins. is objectionable. The best

distribution of the metal is probably that of the American Society of Civil Engineers recommended sections, provided that the rails are of good material and thoroughly rolled, the rolling being as slow and cold as practicable.

The rapid increase in weight of locomotives and cars and train loads has led to the use of heavier and stiffer rails in the sense of girders to carry the increased loads, but in many cases without correspondingly wider heads to sustain the increased wheel pressure ratios per square inch of surface contact between rails and wheels. The result in some such cases has been that the metal of both tires and rails has been overtaxed, excessive wear and flow taking place, and neither wheels nor rails giving as good service as had been expected. With this in view, Mr. P. H. Dudley designed a set of rail sections whose type is shown by the 100-lb. rail of the New York Central Ry., in Fig. 29. It will be noticed that the fillets are of large radius, and that the narrowest part of the web is above the center line. This gives extra resistance to twisting, so that the head will not bend over the web, nor the web over the base. The following is from a statement by Mr. Dudley:

The static pressures under passenger car wheels on rail heads 2¼ to 2⅜ ins. wide, range from 30,000 to 100,000 lbs. per sq. in., while those of locomotive driving wheels range from 110,000 to 150,000 lbs. To sustain such wheel pressures without undue flow and wear, requires not only broad heads, but a high grade of metal in the rails. Comparisons of tire records on the New York Central Ry. before and after the use of the Dudley 80-lb. rail (5⅛ ins. high, 5 ins. width of base, 2 21-32 ins. width of head and 5-16-in. corners of head) show that with an increase of 40% in weight per driving wheel the mileage per 1-16-in. of wear per tire is about the same for the heavier locomotives on the 80-lb. rails, as formerly for the lighter locomotives on the 65-lb. rails. The former carried 17,600 lbs. per wheel, and averaged 19,300 miles per 1-16-in. wear of tire. The latter carried 13,360 lbs. per wheel, and averaged 19,400 miles per 1-16-in. wear. Since the general use of this 80-lb. rail, the locomotives rarely go to the shop to have the driving wheel tires turned unless other repairs are needed, the wear of the tires no longer determining when the engines must go to the shop, as was the case when running on the 65-lb. rails. The mileage before re-turning the tires is from 150,000 to 185,000 miles. These facts show the value of the broad heads in increasing the life of tires as well as of rails.

Mr. Sandberg, the European rail expert, favors wide heads, with large corners, and his type of section is represented by the 72-lb. rail of the Canadian Pacific Ry., Fig. 30. In 1894 he changed his sections somewhat in detail, his modified 100-lb. rail being 5¾ ins. high, 6¼ ins. wide, with a head 3 ins. wide, having ½-in. top corners. He increased the width of the head, but retained the round form with large corners and a top radius of 6 ins. He admits that sharper corners may be used with the American type of rolling stock, having the short, rigid wheel base of the trucks instead of the long, rigid wheel base of European cars with fixed axles, but it may be doubted whether this distinction is of much importance. The width of rail base was increased, so as to avoid the use of tie-plates, for while he advocates their use, he has found it difficult to get them introduced by European railways. The rail section has suffered in consequence, and even with oak ties (and almost certainly with softer ties) the rails will still cut under heavy traffic and wheel loads

One reason for the disfavor with which tie-plates are regarded in Europe is probably the size and weight and cost, and the difficulty of securing flat plates firmly to the tie, so as not to cause rattling. It may be mentioned that some of the so-called Sandberg "Goliath" rails are modified from the original to a section for which Mr. Sandberg disclaims responsibility.

Double-Head Rails.—In Europe the double-headed rail, carried in cast-iron chairs, was early designed, having two symmetrical heads, so that the rail could be reversed and both ends be utilized for wear. Some of the sections were of hour-glass section, with two pear-shaped heads. The indentation of the lower head by the chairs, however, made the turned rails very rough riding, and the rails were also found liable to break, so that as early as 1858 the bull-head section was introduced, having the lower head only large enough to give a seat in the chair and a hold for the wooden key or wedge which secures the rail in the chair. Some years ago about 10 miles of 80-lb. iron double-headed rails were laid on the Boston & Worcester Ry. (now part of the Boston & Albany Ry.), but after 10 years' service the track was relaid with T-rails. The bull-head rail, Fig. 31, is now the standard in England, and is also used somewhat extensively in European countries, India, etc. The Pennsylvania Ry. has some of the 90-lb. bull-head rails of the London & Northwestern Ry., Fig. 31, laid for experimental purposes, some on steel ties, and others in cast-iron chairs on wooden ties, but this track has not been able to stand the heavy traffic on this road. One of the great objections to these rails is that they require two heavy cast-iron chairs (weighing 26 to 56 lbs. each) on every tie, merely to hold the rail up. These chairs involve much really useless material, and the wear of the rails in the chairs limits their life, being even more than the wear at the joints. Many of these rails have rounded heads, as shown, but in some of the modern heavy sections the head has vertical sides and sharper top corners.

Many countries now recognize the disadvantages of the bull-head rail and are adopting a more economical, but equally efficient track of T-rails on metal tie-plates. In England, however, the erroneous idea very generally prevails that a T-rail track is in itself unsafe, and this has even led to the introduction of double-head rails for colonial railways, involving much unneeessary expenditure, which would have been better applied to the construction of a greater mileage of a more suitable type of track. The English track, as built, is very strong and substantial, but very expensive, and an equally good track can be made and maintained at less expense with heavy T-rails. Mr. Freund, of the Eastern Railway of France, has made investigations from which he concluded that theory and experiment show that a T-rail secured to oak ties by screw spikes is as safe from lateral displacement as a bull-head rail in chairs, or a T-rail with tie-plates on pine ties. He further concluded that the T-rail comes nearer to giving its proper service than the bull-head rail, because the life of the latter is limited by the wear of the surfaces in contact with the chairs, and not by the wear of the running surface. In most European countries, except England, T-rails are extensively used, but they are very generally of poor design and very much too light for the traffic, and the consequent poor results in service are among the reasons for the disfavor with which the T-rail section is regarded for main tracks in Europe. European engineers are not, as a rule, well informed

as to modern American track or the successful results of service of good rails under severe conditions of fast, heavy and continual traffic. In some cases a narrow-based T-rail has been adopted, carried in cast-iron chairs, very similar to those for double-headed rails, and secured by large wooden keys, which make an objectionable fastening.

Heavy Rails.—Mr. Sandberg some years ago began, in Europe, a crusade against the policy of using very light sections of steel rails, as the constantly increasing weight of rolling stock and speed of trains made a stronger track system necessary. This, however, was not to be obtained by merely increasing the number of ties, as had been done in some cases, but rather by the adoption of a heavier rail, although many European railways space their ties too far apart. In this country there is still a great mileage of rails too light for safely or economically carrying the traffic to which they are subjected. The advantages of, and the increase in efficiency and economy due to the use of heavy rails of first-class manufacture on tracks carrying heavy and constant traffic, are, however, being more widely recognized, as shown by the very wide adoption of such rails which has been noticeable for the past few years; but the in-

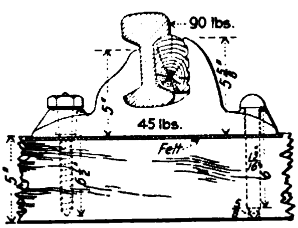


Fig. 31.—Bull-head Rail and Cast-Iron Chair; London & Northwestern Ry.

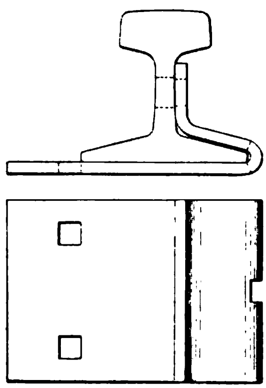


Fig. 32.—Check Plate or Creeper Plate; Boston & Albany Ry.

crease in weight of rail is still lagging behind the increase in traffic and wheel loads, except on the more important lines. Besides being heavy enough to properly sustain the traffic, the rails must be heavy enough to have a margin of safety to provide against the exigencies of badly tamped ties, the heaving of the roadbed in winter, or the effects of flat or eccentric wheels. Mere increase in weight does not necessarily insure improved service, but design and manufacture both come into consideration. For instance, in a rail with a large and soft (or badly rolled) head, the soft metal is more rapidly worn, and as, in many cases, only a certain depth of wear can be allowed before the rail head becomes too rough for service, the large head may really give no more wear than the smaller one, and often gives less wear than a hard, dense, thin head. Some rails have a deep and heavy head combined with a wide, thin base, and rails of such section must of necessity be rolled at such a heat and at such speed that the head cannot be properly compacted and hardened in rolling.

Stiffness is as important as weight in rails under heavy and fast trains, and broad, well-worked heads (rolled as slowly and at as low a temperature as possible) are required for the best efficiency of both rails and wheels. For these reasons some of the old, carefully made 60 and 65-lb. rails gave much better service than poorly designed and hurriedly rolled rails of greater weight, which were laid afterwards. A good 80-lb. rail, however, is a very profitable investment, not only in point of service, but also in giving an easier riding track. The heavier rails do not creep so much, do not bend or crush so much at the joints, and are specially valuable where maintenance work is heavy, as on steep grades, in tunnels, etc. The relation of good heavy rails to economy in operation is shown by experiments in which hauling a train load of 378 tons at a speed of 55 miles per hour required 820 HP. on 65-lb. rails, and 720 HP. on 80-lb. rails, while it was estimated that only 620 HP. would have been required on 105-lb. rails.

The heaviest rail yet laid on this continent is the 110-lb. rail of the Chignecto Ship Railway (Canada), 6¼ ins. high and 6¼ ins. wide, but 100-lb. rails are in use on the New York Central Ry., Pennsylvania Ry., New York, New Haven & Hartford Ry., Chesapeake & Ohio Ry. and other lines. That of the New York Central Ry., Fig. 29, was the first of such weight rolled in this country, and was first adopted for the four-track line approaching the terminal station in New York city, in order to reduce the inconvenience and expense of maintenance and renewals on tracks so crowded with traffic and laid largely in tunnel and in open cut with retaining walls. The St. Clair tunnel of the Grand Trunk Ry. is laid with Sandberg 100-lb. rails rolled in England. The minimum weight economical in ordinary service is 65 lbs., though many roads have used lighter rails even under considerable traffic. In such cases, however, the diminished life of ties and rails, and the increased cost of material and labor for maintenance and renewals, as well as the occasional sums involved in repairs and damage suits after wrecks, more than balance the cost of rails of suitable weight. For ordinary freight and passenger traffic on roads with easy curves and grades, the weight should be from 70 to 75 lbs., while for extra heavy freight traffic or fast passenger trains, or on lines with sharp curves and steep grades, the rails should weigh from 80 lbs. upward. Rails of 80 lbs. per yd. are now in very general use, and rails of 85, 90, 95 and 100 lbs. per yd. are also in service.

In regard to the growing increase in the use of heavy rails, it may be pointed out that while it is most desirable to have rails of ample weight for the traffic, the rail is only one part of the track, and that improvements in ballast, ties, fastenings, joints, etc., are of equal importance in the construction and maintenance of a first-class track. The laying of rails should also be very carefully and thoroughly done, though this is a point that is frequently neglected to a greater or less extent. For instance, new rails carelessly laid on old ties, may be given a wavy surface, or permanent set, due to careless handling or to uneven bearing surfaces, which cannot afterwards be remedied and will materially reduce the beneficial results intended to be obtained by the new rails. With an ordinarily good track, on which light rails are replaced by heavier rails, the work of maintenance and renewals should be very much reduced, owing to the increased weight and stiffness of the rails, which reduces the deflections, so that the joints can be kept in better condition. The number of ties should not be reduced

for heavier rails, as the rail should not be independently considered as a bridge or girder resting upon piers. A fairly large number of ties and fastenings greatly facilitates the maintenance and adjustment of surface, line and gage to ensure an easy riding track, more so than when the supports and fastenings are 33 to 36 ins. apart, as with English track.

Length of Rails.—The ordinary length of rails is 30 ft., but 33 ft., 45 ft. and 60 ft. have been tried to some extent on different roads, and the Norfolk & Western Ry. has 85-lb. rails, 60 ft. long, which are not found particularly awkward to handle. Several railways use 60 ft. rails on bridges and in tunnels, and the standard length of rail on the Louisville, New Albany & Chicago Ry. is 33 ft. for a 75-lb. rail of the section recommended by the American Society of Civil Engineers. The Lehigh Valley Ry. has a considerable mileage of rails 45 ft. long. A report on the desirability of long rails, and the proper length for same, was made by a committee of engineers to the General Managers' Association of Chicago, in 1894. The conclusions were, in brief, as follows: 1. There would be at first an additional cost for manufacture, and a greater proportion of second quality rails; 2. Renewals of single rails would be more expensive and troublesome; 3. Transportation would be more expensive; 4. Unloading from cars would require a greater number of men, though not a greater number per ton, and no greater than is ordinarily available. The benefits resulting from the use of the longer rails were enumerated as follows: 1. Economy in first cost and maintenance of joints; 2. Fewer accidents and breakages at joints; 3. Smoother riding track. The report recommended miter-cutting the rail ends, at an angle of about 55°, and that the expansion spacing at joints should be ⅝-in. at 0° F. There are some difficulties in turning rails as long as 60 ft., especially on a narrow right of way.

Continuous rails, with the ends welded together in the track, are being tried on street railways, and some experiments have been made on steam railways with rails laid without expansion spacing and spliced by riveted angle bars. In June, 1889, Mr. T. T. Gleaves laid on the Durham Division of the Norfolk & Western Ry., 3 miles of the continuous "self-surfacing" track patented in 1886 by Mr. P. Noonan, a section foreman. The rails were 56-lbs. per yd., laid on ordinary ties completely buried in the earth, and the spike heads were left ⅜-in. clear above the rail base, so that the wave motion or undulation of the rails would not affect the spikes or ties. As this motion was in advance of the wheels, there was no battering of the ties, and the motion of a train was said to have been as smooth and easy as on heavy rails in stone ballast. The joints were secured by splice bars with ¾-in. rivets, making the rails continuous and without any allowance for expansion. At each end of the three-mile section were switch points to allow for the expansion of long stretches of rail, and at frogs and switches at stations of course the rails could move longitudinally. The track was turfed over, and 3-in. terra cotta drain tiles were inserted to carry the water out beyond the track. After being laid, the track was not lined or surfaced for 18 months, the only maintenance expense being for a watchman, although engines weighing 104,000 lbs. were frequently run over it at a speed of 50 miles per hour. The ties were found to decay more quickly by being buried in the earth and becoming water-logged, as might have been expected, and the track got somewhat out of surface, owing mainly to the fact that it was not laid on a compact roadbed, but in wet clay cuts and

TABLE No. 4.—DIMENSIONS OF RAIL SECTIONS.

Railway	C. & O.	N. Y. C.	Penna.		B. & A.	L. V.	....	Penna.	N. Y. C.	Mich. C.	N.Y.C.	Can.Pa.	....	Que.C.	C.B.&Q.
Type of Section	A. S. C. E.	Dudley	P. R. R.	Sandb'g	....	Sayre	A.S.C.E.	P. R. R.	Dudley	A.S.C.E.	Dudley	Sandb'g	A.S.C.E.	....	....
Weight, per yard ... lbs.	100	100	100	100	95	90	90	85	80	80	75	72	70	60	56
Height ... ins.	5¾	6	5½	5¾	5 1/32	5	5⅜	5	5⅛	5	5	4 13/16	4⅝	4⅜	4 1/16
Width of base ... ins.	5¼	5¼	5½	6¼	5½	5	5⅜	5	5	5	4¾	4½	4⅝	4⅜	4 1/16
Width of head, top ... ins.	2¾	....	....	3	2 27/32	....	2⅝	...	....	2½	....	2¼	2 7/16	2¼	2 7/32
Width of head, bottom ... ins.	2¾	3	2¾	3	3	2¾	2⅝	2 9/16	2 21/32	2½	2⅜	2¼	2 7/16	2¼	2 7/32
Side of head, slope ... degree.	Vert.	4	4	Vert.	4	5	Vert.	4	4	Vert.	4	Vert.	Vert.	Vert.	Vert.
Depth of head ... ins.	1 45/64	1⅝	2	1⅞	1 9/16	1 53/64	1 19/32	1 11/16	1½	1½	1⅜	1⅝	1 11/32	1¼	1 17/64
Height of web ... ins.	3 5/64	3 13/32	2 9/16	....	2 15/32	2 19/64	2 35/64	2 7/16	2¾	2⅝	2¾	2 35/64	2 15/32	2 5/16	2⅛
Depth of base ... ins.	31/32	31/32	15/16	....	1	13/16	59/64	⅞	⅞	⅞	⅞	59/64	13/16	13/16	47/64
Thickness of web ... ins.	9/16	19/32	9/16	17/32	⅝	⅝	9/16	9/16	17/32	35/64	17/32	½	33/64	½	15/32
Thickness of edge of base. ins.	5/16	5/16	⅜	⅜	5/16	⅓	¼	5/16	¼	¼	9/32	....	¼	....	....
H'ght to cen. of bolt hole. ins.	....	....	2 7/32	....	2 9/32	2 1/16	....	2 1/32	2¼	....	2⅛	2 15/128	....	....	....
Radius, top of head ... ins.	12	14	10	5¾	14	12	12	10	14	12	14	6	12	12	12
" top cor. of head .. ins.	5/16	5/16	7/16	½	5/16	½	5/16	7/16	¼	5/16	¼	½	5/16	¼	¼
" bot. cor. of head .. ins.	1/16	1/16	⅛	Sharp	⅛	⅛	1/16	⅛	1/16	1/16	1/16	Sharp	1/16	....	⅛
" top fillets ... ins.	¼	½	¼	....	½	¼	¼	¼	½	¼	⅜	⅜	¼	¼	⅜
" bottom fillets ... ins.	¼	5/16	¼	....	5/16	¼	¼	¼	5/16	¼	5/16	⅜	¼	¼	⅜
" corners of base .. ins.	1/16	1/16	3/16	....	1/16	1/16	1/16	5/32	1/16	1/16	1/16	⅛	1/16	⅛	1/16
" sides of web ... ins.	12	14	8	Vert.	14	9	12	8	14	12	14	Vert.	12	12	11
Edge of base, rd. or vert..	Vert.	Vert.	Rd.	Vert.	Vert.	Vert.	Vert.	Rd.	Vert.	Vert.	Vert.	Vert.	Vert.	Rd.	Vert.
Fishing angles of head ... degree.	13	14	13	20	14	14	13	13	14	13	14	15	13	13	13
" " of base ... degree.	13	14	13½	20	14	14	13	13	14	13	14	15	13	13	13
Metal in head ... per cent.	42	40.8	49.0	46	....	47.8	42	....	42.2	42	41	37.6	42	....	41.8
" in web ... per cent.	21	23.5	18.5	17	....	18.2	21	....	21.1	21	23	18.1	21	....	21.7
" in base ... per cent.	37	35.7	32.5	37	....	34.0	37	....	36.7	37	36	44.3	37	....	36.5

on banks that settled in sags. During the same period of 18 months, there were expended $1,890 in labor for keeping the adjoining three-mile sections in fair condition. With such a track on good ballast some interesting results might be expected.

Dimensions of Rails.—In Table No. 4 are given the dimensions of a number of modern standard rail sections. The first four show the comparative designs of four principal types of sections. The "American Society of Civil Engineers" and Dudley types are undoubtedly the best, the latter being somewhat the stiffer and being designed for use with tie-plates, hence the narrower base. The Sayre, Sandberg and Pennsylvania Ry. types are defective in the roundness and heaviness of their heads.

Manufacture.—The wrought iron rails were made of bars placed in layers to form a "pile," which was then heated to welding heat and rolled to the finished rail section in the usual way, the several pieces of the original "pile" being more or less completely welded together. As the traffic and weight of rolling stock increased, these rails began to give trouble by splitting and by lamination of the head, due to the separation of imperfect welds. This led to the introduction about 1857 of so-called "steel" rails, made of a high grade of homogeneous iron rolled from solid ingots and consequently without the weak points of the welds. Steel rails were first rolled in England about 1855, and in this country were rolled experimentally in 1865 and to order in 1867, when the improvement of the Bessemer process of 1862 (largely due to and introduced in this country by A. L. Holley), led to greatly increased facility of manufacture and consequent decrease in cost. These first steel rails were rolled under the direction of Mr. R. W. Hunt, and the men were paid double rates per ton, while the steel was rolled comparatively cold. When steel was still enormously costly, iron rails with steel tops were introduced, but were not satisfactory, as it was not found possible to securely fasten the cap to the rail. The Bessemer process, with Holley's improvements, and the invention of the Siemens-Martin method of manufacture, and the consequent introduction of steel rails at reasonable prices, were great factors in the enormous railway development of the past 25 years, but, as noted further on, the cheapness and rapidity of manufacture have to some extent been carried beyond the economical point. The rails do not fail by splitting and lamination, the metal being homogeneous, but by (1) the normal abrasion of the head, (2) the cutting out and bending at joints due to the blows of the wheels, (3) the flow of the metal of the head under heavy wheel pressures, and (4) occasionally by fracture, though steel rails are less liable to fracture in cold weather than iron rails.

In the manufacture of Bessemer steel rails, pig irons of the desired grade are melted in a cupola, tapped into a ladle, and poured into the Bessemer converter. A certain proportion of scrap iron is then poured in, and air at about 25 lbs. pressure is then blown in from the bottom of the converter, practically burning out the carbon, silicon and undesirable constituents. The proper degree of carbon is then added by a charge of spiegeleisen, and the molten steel is then poured into the casting ladle and thence into the vertical ingot molds. The ingots are generally about 16 x 19 ins., 4½ ft. long. They are kept in a furnace called a soaking pit, until rolling. The ingot is first rolled in a blooming mill, which reduces it in section and makes it a bloom or bar about 7¾ ins. square. The bloom is then cropped at the ends, to cut off any spongy parts, then reheated,

and rolled in a rail mill, the roughing rolls of which give it an approximate shape, while the finishing rolls complete the work and form the name of maker, date and weight of rail in raised letters on one side of the web, so that each rail can be traced. The blooms are rolled to the length of one to four rails, according to weight. From the finishing pass through the rolls, the rails are run to the saws and cut to length (usually 30 ft. 6½ ins., which will be 30 ft. when cold), then to the cambering machine to give them such a camber that in shrinking they will become perfectly level (6 to 12 ins., according to the distribution of metal in the section), then to the hot beds to cool, and then to the straightening press. There the burr left by the saw is chipped off, the ends are filed, and the rail hammered with a gag to take out horizontal kinks. The gag should not be applied to the rail head, and some better system of straightening is much to be desired, as the kinks sometimes reappear when the rail is laid, and gag marks on the head form places for wear to start. The rails are then measured for length, and, if this is correct, they are then drilled for the bolt holes and placed on the inspection or shipping beds.

One of the most important chemical components of rail steel is the carbon, the proportion of which ordinarily ranges about as follows, according to the views of individual designers or makers: 60-lb., 0.40 to 0.45%; 70-lb., 0.45 to 0.50%; 80-lb., 0.45 to 0.55, or even 0.60%. The maximum proportion is 0.65 to 0.75%, as specified for the 100-lb. rails of the New York Central Ry., but it is rarely, if ever, that 0.7% is exceeded even in these rails. The object of the high carbon proportion is to give hardness to the steel, but it is liable to render it brittle unless special care is taken in proportioning the other chemical components and in the process of manufacture. Under these conditions, however, a rail can be made combining hardness (to resist wear) with toughness (to resist fracture), and such rails have given most excellent results in service. The Boston & Albany Ry. has had the Dudley 95-lb. rails (with 0.6 carbon and 0.06 phosphorus) in service since 1891, but out of 75,000 tons not one rail broke during the winter of 1892-93, although subjected to a minimum temperature of −30° F. The idea was at one time advanced that soft or low-carbon steel would be best for rails, and such rails were introduced to some extent, but the fallacy was very soon exploded. Silicon makes the steel fluid and dense, so as to produce solid ingots and small crystallization. In the New York Central Ry. rails the silicon varies from 0.1 to 0.15% in the 65-lb. sections, to 0.1 to 0.25 in the 100-lb. sections. In all the rails the manganese must be between 0.8 and 1%; sulphur not exceeding 0.069% and phosphorus not exceeding 0.06%. Some designers, however, allow 0.085 or even 0.1% of phosphorus. Manganese is required for chemical purposes during the blow in the converter, and gives a certain ductility in rolling, but tends to cause coarse crystallization in the rail and flow of metal under traffic. Sulphur and phosphorus are objectionable impurities, the former tending to make the metal seamy and the latter tending to make it brittle. The chemical proportions for rails cannot be stated uniformly or arbitrarily, but the specifications must be prepared with regard to the quality of ore to be used, and the weight of the rail. Some roads do not specify the chemical composition, but merely stipulate that the rails must pass certain tests. Two Harveyized steel rails were put down for test on the Delaware, Lackawanna & Western Ry., and

showed good results in wear for about two years, so far as so limited an experiment could show anything. By this process additional carbon is absorbed by the head after the rail is manufactured, and analysis showed 0.76% for 1-16-in. depth of the head, 0.42% at 2-16, and 0.3% at 3-16.

The design and methods of manufacture of a rail are fully as important as the chemical proportions in securing a good rail. A thick, heavy head cannot be given such a close texture as a thinner head, especially if the former is combined with a wide thin flange, as when such a flange is at the proper heat during rolling the head will be entirely too hot for good work. Such a rail section must be rolled hot and quickly, will not cool uniformly, and will have an open and soft texture. For this reason the modern tendency is to use comparatively shallow heads of good width, the metal of which can be rolled slowly and at a comparatively low temperature, and thus be thoroughly compressed, hardened and compacted to the firm and close texture of grain which will give the best wearing quality. Besides this, such a section gives a more uniform distribution or balance of the metal, so that there will be less warping by internal strain due to uneven cooling. One of the difficulties in making a good rail is that of obtaining a good flange or base, as the edges of the base are the thinnest parts of the rail, and if the base is too wide and thin there is difficulty in getting it to fill out to the full designed width and in preventing flaws. For this reason it is easier to roll a good rail of the bull-head section than of the T or flange section, but the use of the metal tie-plate at once eliminates the necessity of a very wide base.

It is now generally recognized that rail steel should be chemically and physically hard, which hardness may be, by proper manufacture, combined with toughness, so that the rails will not be liable to fracture under shock in cold weather. Until a few years ago, rail specifications, supervision of manufacture and inspection of rails were very lax, and the quality of rails naturally deteriorated, the manufacturers turning out just such rails as would be accepted, so that at one time engineers and rail makers claimed that heavy rails could not be made which would give as good service as the smaller and lighter rails. This has been changed very considerably, however, but there is now undoubtedly too great a tendency to consider cheapness as the first essential, and as the manufacture is certainly affected by the price it follows that the cheaper rails are very likely to be of inferior quality, due very largely to their having been "squirted through the rolls," as the hot rolling has been termed. Defective specifications and carelessness in manufacture account for the fact that many heavy modern rails have been found to give less wear or service than lighter rails bought when rails were dear and their manufacture more carefully attended to. Of course the labor charges have been reduced with the price of the rails, but not in the same proportion, and as the men are paid by the ton and have therefore an interest in a large and rapid output, inspection on behalf of the purchaser is necessary. In 1875, Mr. Ashbel Welch, Chairman of the rail committee of the American Society of Civil Engineers, put the economical statement of the case very plainly as follows: "An unwise saving of a dollar to the manufacturer, or a little unfaithfulness in the workman, will probably reduce the value of the rails ten or twenty dollars. Ten or 15% added to the ordinary work on rails would double their value. An expert rail maker knows this very well, but he cannot put the $10 extra work on a ton in or-

der that it may be worth $60 more to the purchaser, who will not allow him any part of the $10 out of the $60 he makes. The railway agent who purchases may also know all this, but he cannot follow his own judgment, for he knows his directors will say he paid $10 per ton more than the market price. It is thus that the interests of stockholders are sacrificed."

The New York, New Haven & Hartford Ry. had 60-lb. English steel rails laid in 1870, which, after 21 years' hard service in the main track, showed little loss of metal in the head by abrasion or by the flow of the metal. Some of these rails were given a cold rolling to harden the skin, but there did not appear to be any increased rapidity of wear after the skin had been worn through. Others were of comparatively high carbon. In 1889, Mr. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry., stated that on his road there were 65 to 70-lb. rails that, when new, would stand less traffic than 56 or 57-lb. rails made under the same specification, which certainly seemed to indicate that as the mass of metal is increased, more thorough working of the metal is required in the process of manufacture. In one case, on that road, 8 miles of 67-lb. rails were removed in two years as no longer fit for service, while joining them, and carrying the same traffic, were 58-lb. rails which had been in use for 8 or 10 years, and were still in good condition. The writer is strongly in favor of paying a good price for a good article, and it is safe to say, as the result of ample experience, that good rails bought at the price which they are really worth are far more economical than "cheap" rails bought at the price which they are worth.

Rails should be rolled for several of the final passes at a comparatively low temperature, and slowly, so as to give the metal a close texture and smooth surface. The fineness of grain of the steel is governed by the work applied to it as its heat decreases, while the wearing quality of the rails depends largely upon the closeness of grain of the metal in the head. This is especially the case with a high-carbon steel. The sawing of the rail ends, the cooling, straightening and loading should be carefully looked to by the purchaser's inspector, and the rails not allowed to be thrown about, as any kink or notch is likely to start wear or a crack. If the straightening is not particularly looked to, many rails will have to be straightened by the trackmen before being put in the track, and for this reason it is sometimes found well to depute a good foreman to inspect the rails for straightness at the mill and to supervise the loading. In some cases the specifications contain a guarantee clause requiring the manufacturer to replace all broken or worn rails that have to be renewed within a certain number of years, and this is particularly the case in English practice. This system is useful where the railway is so situated in relation to the rail maker as to allow of the rails being examined from time to time to see if they are fairly treated, but when the railway is far distant it is probably better for the purchaser to look after his interests by good specifications, and by good inspection to make sure that he gets what his specifications demand before the rails are paid for. Nevertheless, rails for India, Australia, etc., are manufactured in England under the guarantee system. Rail inspectors should be familiar with both rail manufacture and railway track practice. As to the details of manufacture it is probably best, as advocated by Mr. Sandberg and other rail experts, to let the manufacturer choose, to a great extent, his own method of manufacture, and to carefully inspect and test the rails thus produced.

Rails are usually tested by the drop test, with a weight of 2,000 lbs. falling 16 ft. for rails of 70 lbs. per yd. and less, and 20 ft. for rails heavier than 70 lbs. per yd. The weight falls on a rail butt placed with head or base upward and resting on supports 3 ft. or 4 ft. apart for weights of rails as above noted. The specifications of the New York Central Ry. require that in 90% of such tests the butts stand without breaking, and show at least 5% elongation in the inch under greatest tension. Other roads require only 3 to 4% elongation. Spaces of 1 in. marked off on the rail under the point of impact enable the elongation to be readily determined.

It is very common to require that rails must be laid with the brand uniformly on the outside or inside of the track, but there does not seem to be much importance in observing this, especially if it requires many rails to be turned, as both sides of the head are alike, except when bad or worn rails are used, and such rails should be detected during inspection.

Life and Wear of Rails.—The life of first-class 60 to 80-lb. steel rails was given by Wellington in his "Economical Theory of Railway Location" (1887) as about 150,000,000 to 200,000,000 tons. There are from 10 to 15 lbs. of metal, or ⅜-in. to ⅝-in. depth of head, available for wear, and abrasion takes place at the rate of about 1 lb. per 10,000,000 tons, or 1-16-in. per 14,000,000 to 15,000,000 tons of traffic. The rate of wear is increased about 75% by the use of sand by the locomotives. The failure of modern rails, as a rule, is due more to deformation of section at and near the joints than to abrasion proper, and this deformation and crushing are largely due to the heavily loaded driving wheels, the wear from which is estimated at 50 to 75% of the total. Heavy freight engines may have three or four driving axle loads of 30,000 to 38,000 lbs. on a wheelbase of 12 to 15 ft. The area of contact between the driving wheels and rails is an oval about 1 x ¾-in., or with worn tires or worn rails 1 x 1½ ins., with an area of 1.07 sq. in. The maintenance of rails ought not to exceed ½ ct. or 1 ct. per train mile, but it is very generally as much as 3 cts., owing partly to work on side tracks. About half the metal in the rail head is available for wear, but the full depth of wear is not obtainable in main track, as the rails would then be too rough for service; about ¼-in. is the limit of wear in main track, the rails being then removed to branch or side tracks (see "Curves").

The flow of metal in the rail head is very evident in deep headed rails of 0.35 to 0.4% carbon, especially under heavy wheel loads on grades and curves. For this reason stiff hard rails are specially valuable on busy lines with steep grades; the wear, flow and creeping being less, as well as the deflection and cutting out at joints. In tunnels there is apt to be abnormal wear due to the use of sand on damp rails, and also corrosion due to the effect of the dampness, the gases from the smoke and the drippings from coal, ore and refrigerator cars. Serious vertical and lateral bending of the rails, or even fracture, are often caused by "dead" locomotives hauled in freight trains with the rods taken down, or by running engines with small wheels at excessive speed, as the unbalanced forces due to the counterbalance weights in the driving wheels have then a powerful and destructive effect upon the rail.

In all worn rails taken out of main tracks the proportion of metal lost by wear is comparatively small, and the bulk of the rail becomes scrap. In order to increase the life of rails a process has been patented and put in operation by Mr. E. W. McKenna, formerly General Superintendent of the Great Northern Ry., by which the old rails are heated in a reverbera-

tory furnace to a cherry red heat, or about 1,200° F., and then given two passes in a rail mill. Old 65-lb. rails, reduced to 64 lbs. by wear, have been rolled to a 58½-lb. section, the elongation usually allowing of cutting off crop ends for a standard 30-ft. rail. The quality of the steel is improved by the operation, the old rails having been of somewhat open texture, while care is taken that the heat is not sufficient to affect the chemical composition of the metal. With the same object Mr. Manning, Chief Engineer of the Baltimore & Ohio Ry., has patented a rail with the head projecting farther on one side of the head than the other, resembling somewhat the Vietor rail (Germany), noted under "Rail Joints."

Expansion Spacing.—A space is usually left between rail ends in the track to allow for the expansion and contraction of the metal. This is usually provided for in tracklaying by using angle-shaped shims or strips of iron, with the legs of the thickness for spacing in warm and cold weather. Wooden spacing shims (such as the staves of spike kegs, sometimes used) should never be allowed.

The expansion of a steel rail 30 ft. long during a rise of temperature from $-20°$ to $+140°$ F. would be about 7-16-in. The coefficient of linear expansion of steel for 1° F. is given by Prof. Merriman in his "Mechanics of Materials" as 0.0000065. The expansion (in inches) of a steel rail 30 ft. long for one degree increase in temperature would therefore be $0.0000065 \times 30 \times 12 = 0.00234$.

In Table No. 5, compiled by Mr. W. C. Downing, Engineer of Maintenance of Way of the Vandalia Line, is given the variation in length of a rail for each 10° increase in temperature for a range of 160°, or from $-30°$ F. to $+130°$ F., the rails being assumed to be in contact at the latter temperature.

TABLE NO. 5.—EXPANSION OF STEEL RAILS.

Temp., deg.	Variation, in.	Variation, in.	Thick. of Exp. shim, in.	Temp., deg.	Variation, in.	Variation, in.	Thick. of Exp. shim, in.
−30	.3744	24-64	6-16	50	.1872	12-64	3-16
−20	.3510	23-64	"	60	.1638	10-64	"
−10	.3276	21-64	"	70	.1404	9-64	"
0	.3042	19-64	5-16	80	.1170	7-64	2-16
10	.2808	18-64	"	90	.0936	6-64	"
20	.2574	16-64	4-16	100	.0702	5-64	1-16
30	.2340	15-64	"	110	.0468	3-64	"
.40	.2106	14-64	"	120	.0234	1-64	"
				130	.0000	....	....

The Atchison, Topeka & Santa Fe Ry. specifies a spacing of ⅛-in. for hot summer weather, ¼-in. for moderately cool weather, and ⅜-in. for cold weather in winter. The Illinois Central Ry., Baltimore & Ohio Ry. and Louisville & Nashville Ry. specify 1-16-in. for very warm weather, ⅛-in. during spring and autumn. and 5-16-in. during the coldest weather. When there are great changes of temperature during the day, one set of shims should be used up to about 9 a. m. and after 3 or 4 p. m., and another thinner set from 9 a. m. to 3 p. m. (see chapter on "Tracklaying"). The spacings specified by two roads in widely separated parts of the country are as follows:

TABLE NO. 6.—EXPANSION SPACING FOR RAILS.

Southern Pacific Ry. Degrees, Fahr.	Spacing, inches.	Quebec Central Ry. Degrees, Fahr.	Spacing, inches.
0 to 32	¼-in.	30 to 40	⅜-in.
32 " 50	13-64 "	50	5-16 "
50 " 75	9-64 "	60	¼ "
75 " 90	3-32 "	70	3-16 "
90 "100	3-64 "	80	⅛ "

Creeping.—Rails have in many places a decided tendency to creep or travel along the track, both up and down grade, due to the wave motion, the unbalanced traffic in one direction, the action of braked wheels, the contraction and expansion due to changes in temperature, etc. This creeping is more especially troublesome as a rule on steep grades, on bridges, and on swampy roadbeds, but may develop at any place. With fish-plate supported joints the corners of the rail base may be clipped off, forming notches into which spikes may be driven, or spike slots may be cut in the edge of the rail base, to come over the joint tie. With fish-plate suspended joints the spike slots must be so arranged as to come upon the shoulder ties. With angle-bar joints the flanges of the bars have usually one, two or three slots, according to whether they are for supported, suspended or three-tie joints. Sometimes the spikes are driven against the ends of the bars, but this is not good practice and the spikes are hard to remove. The narrow-flanged angle bars favored by some roads do not give much hold for the spikes, and the latter are therefore likely to be crowded out of the slots, leaving the rails free to creep. The wide-flanged bars are the best, with slots about ⅞-in. deep, and still better are those having holes instead of slots, so that the bar cannot get away from the spikes or screws, while the spikes on both sides then offer resistance to any lateral movement of the rail. Heavy rails usually give less trouble than lighter rails in this respect, and any ordinary creeping can usually be avoided by the use of heavy rails and carefully spiked angle bars. Where special trouble is encountered, it is best to anchor each rail at the middle of its length by means of a check or creeper plate, or by slotting the rail, but the latter plan is decidedly bad. In Fig. 32 is shown a combined tie-plate and check-plate used by the Boston & Albany Ry. The Chicago, Burlington & Quincy Ry. uses two pieces of angle bar 5 ins. long, bolted to the middle of the rail and spiked to the tie. By thus holding the rail at the middle the motion of each is independent and not cumulative, and the rail is weakened less by a bolt hole than by a spike slot.

Many curious instances of such creeping are familiar to all track men. In the case of a 60-lb. rail on a pile trestle at Galveston, the creeping followed the direction of the heaviest traffic, traveling about 9 ft. per month. This was stopped by full spiking the slots in the angle bars, placing blocks between the shoulder ties of suspended joints. The spikes were 7 ins. long, 5-16-in. square, with wedge or side points, as the ties were only 2 ins. thick, and the spikes were driven through into the stringers. When a foreman, through misunderstanding of orders, began to remove the slot spikes, the creeping bent the spikes, the angle bars even mounting some of the spikes. In general, rails are allowed to creep on bridges (except where the motion is excessive) and foremen are instructed not to slot spike the joints on bridges, so as to avoid throwing undesirable strains upon the structures. In one case, however, the creeping under traffic in one direction on a trestle 400 ft. long, caused the angle bars (unspiked) to catch the spikes on adjoining ties and pull the entire deck 8 ins. up a 1% grade. The creeping on the St. Louis (Eads) bridge has been something abnormal, and was discussed by Prof. J. B. Johnson in "Engineering News," New York, in 1884. The bridge is double track, and has a rise of 5 ft. at the center of its length of 1,600 ft. Here the creeping is proportional to the traffic, but upon the east approach of 2,500 ft., the effect of the grade of 1.56% is apparent. This track requires constant attention.

During the last half of 1893 the creeping on the east and west approaches averaged about 60 ft. per month on each side, while on the bridge structure it was as follows:

TABLE NO. 7.—CREEPING OF RAILS ON THE ST. LOUIS BRIDGE.

	Inbound track.			Outbound track.	
1893.	North rail.	South rail.	1893.	North rail.	South rail.
July	13 ft. 1 in.	13 ft. 3 ins.	July	10 ft. 0 in.	7 ft. 2 ins.
August	13 " 0 "	12 " 0 "	August	7 " 0 "	9 " 10 "
September ..	6 " 2 ins.	11 " 3 "	September ..	10 " 1 "	8 " 8 "
October	6 " 11 "	10 " 3 "	October	9 " 2 ins.	7 " 9 "
November ..	2 " 1 in.	3 " 7 "	November ..	9 " 2 "	7 " 6 "
December ..	0 " 11 ins.	2 " 1 in.	December ..	9 " 7 "	7 " 0 in.

The creeping of track (rails and ties together) occurs on swampy roadbeds, owing to the action of the wave motion under traffic. To resist this on a track used by consolidation engines with a weight of 120,000 lbs. on the driving wheels, the Minneapolis, St. Paul & Sault Ste. Marie Ry. used ties 10 and 12 ft. long, with angle bars spiked to two ties at the center of the rail, to keep the rails from creeping on the ties. The use of cinder ballast and heavy rails also acts to check this movement.

CHAPTER 6.—RAIL FASTENINGS AND RAIL JOINTS.

Rail Fastenings.

One of the weakest points of the track is in the fastening of the rails to the ties, for in spite of the increase in weight of rail, and the enormous increase in wheel loads, train loads, traffic and speed, the almost universal fastening is still the ordinary square spike developed from Col. Stevens' "hook-headed" spike of 1830. This was an excellent device in its day, and is still a good device for light rails, rolling stock and traffic, but it has been outgrown by modern track with 80 to 100-lb. rails carrying the great weights of modern locomotives and trains, and is an unsatisfactory and uneconomical fastening for first-class track. It is most desirable, for safety and for economy in maintenance, that some more efficient fastening should be generally adopted than the spikes, which are really nothing more than large nails, and depend solely upon the friction of the fibers of the wood for their hold in the tie. The ordinary rough spike is a disgrace to a main track; as it tears and crushes the fibers so barbarously that its hold is comparatively slight. Though improved spikes, with smooth sides and clean sharp edges and points are being used to a considerable extent, and get a better and more secure hold in the wood, yet the spike, in principle, is not a sufficient fastening for rails which carry heavy trains at high speeds. Even on good roads, with careful maintenance, it is common to see loose spikes, forced outward or pulled upward by the movement of the rail. Newly driven spikes in ordinary ties have a tolerably firm hold, but this is rapidly reduced by the constant vibration and working of the rails under traffic, and by the "spike killing" of the tie by the continual working up and driving down of the spikes, which latter work is often a considerable proportion of the work of maintenance.

The spike being held by friction only, the vertical motion of the rail, or its wave motion under traffic, gradually draws it out of the tie, while the lateral thrust on the rail by wheels (especially on curves) tends to tilt

the rail outwards, drawing the inner spike up and pressing the outer spike back into the wood. This enlarges the spike holes, besides wearing and abrading the neck or throat of the spike. The great advantages of the tie-plate in preventing this tilting of the rail and consequent loosening of the spike, and in preventing the "necking" of the spike have already been pointed out. Boring holes for the spikes would prevent much checking and cracking of the wood, and a hole of proper diameter would increase the holding power and adhesion of spikes. Many improved forms of fastenings have been designed, and several tried to a greater or less extent, while the defects of the spike have been pointed out again and again, but at the present time the maintenance of way department has still, as a rule, only the old-fashioned spike to consider, and must make the best of it. For heavy track a fastening should be adopted which will give a positive hold on the tie, and not merely the frictional hold of a spike.

Spikes.—The most commonly used spike is of the form shown at A, Fig. 33; the standard size being 5½ ins. long under the back of the head, 9-16-in. square, with a blunt chisel-edge about 1¾ ins. long and a head about 1⅜ x 1 3-16 ins. This is the spike used by the Pennsylvania Ry. Such spikes weigh about half a pound each, and are put up in kegs of 200 lbs. A keg contains about 450 spikes ½ x ½ x 5 ins.; 400 spikes 9-16

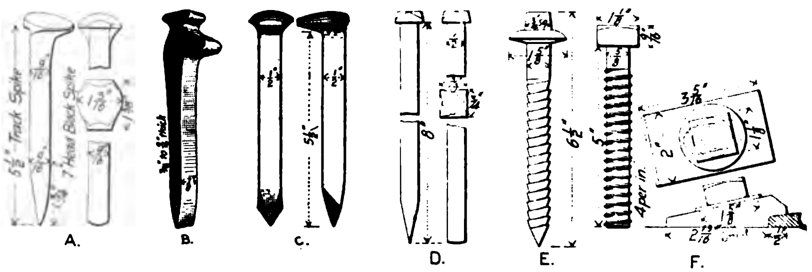


Fig. 33.—Rail Fastenings; Spikes and Screws.

x 9-16 x 5 ins.; or 375 spikes 9-16 x 9-16 x 5½ ins., the length being measured under the head. As a rule, they have more or less rough surfaces and blunt points, which crush and tear the fibers of the wood under ordinary conditions. This state of things is familiar to every track man, but it is as well to point out that the effect depends very largely on the spiker. A careful man can so drive a bad spike as to do comparatively little damage to the tie, while a good spike carelessly driven may do almost as much injury as a bad spike. A great improvement may be effected by the use of carefully made spikes, having clean and even (not smooth) surfaces, sharp edges and sharp points, so that the fibers will be cut by the point and pressed back by the body of the spike. The fibers thus compressed and tightly packed, with their ends slightly bent down against the faces of the spike, offer a strong resistance to the pulling of the spike, and tend to prevent the entrance of water. Various forms of spikes have been devised, but extensive experiments made at the St. Louis Bridge and elsewhere have proved that it is by no means so easy to improve the holding power of a well-made spike as might be supposed.

Many of the patented forms have twisted, jagged or grooved surfaces, but attempts to increase the holding power by ragging and jagging the spikes have been mainly unsuccessful, as the projections tear the fibers, unless the projections are so small as only to press the fibers back and allow them then to spring back against the body of the spike. In any case a well-shaped and well-made spike of the ordinary form will generally have as good a hold. The head is capable of improvement by being made larger and heavier, and one form has the back almost straight, with the top surface of the deep head curving down onto the rail, the head projecting further than usual over the rail base. Spikes used on foreign railways, where they are sometimes used alternately with screw spikes or bolts, have usually larger and heavier heads than the American spikes.

The Goldie steel spike, C, Fig. 33, is made with the intention of doing as little damage to the tie as possible, the end being ground to a sharp point, instead of a chisel edge, while both edges and faces of the point are made in a slope so as to increase the cutting and wedging effect. The shank is made with clean surfaces and sharp edges for the same reason. The Greer steel spike, B, Fig. 33, is of varying section, 5½ ins. long, ⅞-in. wide, and from 5-16 to 9-16-in. thick. The point is ground to a sharp chisel edge, and the head is specially designed to insure straight driving, the blows of the maul striking the centre of the head and not being liable to strike the lip which holds the rail base. The shape of the head also affords a good hold for the clawbar in drawing spikes. The swelling shape of the shank is claimed to increase the holding power of the fibers, while the increased width gives greater resistance to lateral thrust. Longer spikes are used at headblocks, as shown at A. Crossing spikes are of larger size, and the standard crossing spike of the Pennsylvania Ry., shown at D, Fig. 33, is ½-in. square and 8 ins. long under the head, which is ¾-in. square. Boat spikes are better and cheaper than track spikes for fastening the planks of highway crossings, and the latter are too short for 4-in. planks. These boat spikes are usually ⅜-in. square and 7 ins. long. Where spikes are driven into longitudinal timbers, as in some cases on bridge floors, they are made with the chisel edge reversed from the usual position, being at right angles to the rail, so as to cut across the fibers, as on crossties.

Numerous experiments made on the holding power of spikes show that there is a great variation, due to the kind and quality of the wood and the condition of the spike. As an average, a newly driven 9-16-in. well-made common spike, in a good oak or pine tie, may be assumed to have a resistance to pulling of 3,000 to 3,500 lbs., for though resistances up to 7,000 lbs. have been recorded, they cannot be considered as being obtained in ordinary conditions of track and spike driving. The constant upward pull exerted by the rail under the influence of traffic very soon begins to lessen the resistance, and spikes redriven in their own or other old holes have, of course, a materially decreased holding power. In inferior woods, the initial resistance may be from 800 to 1.800 lbs. Lag screws, under ordinary conditions, may be assumed to give a resistance of 5,000 to 8,000 lbs. in oak, or 4,000 lbs. in pine, and this is maintained for a much longer time than with ordinary spikes.

Screw Spikes.—These have long been common in foreign practice, sometimes holding the rail direct by the spike head, and sometimes by means

of a clamp, as shown in Figs. 20 and 21, but in this country they are very little used. The Southern Pacific Ry. has used them in redwood ties, which do not hold the ordinary spikes well. Metal tie-plates are used in connection with these fastenings, as already noted. The holes are bored by machinery, the boring bits being adjustable, and templates are used to set them to bore holes for rails of different widths of base as well as for joint ties. The standard section of tie is 8 ins. wide and 7 ins. deep, and the holes are bored 7-16-in. diameter and 5 ins. deep for screw spikes ⅝-in. diameter and 5⅝ ins. long over the head. The spike is shown at E, Fig. 33, and is sharp pointed and has a head 1⅝ ins. diameter (bearing directly upon the rail base) with a square projection for the socket wrench. The Pennsylvania Ry. uses screw spikes for fastening the angle bars of its 100-lb. rails to the ties (34-in. angle bars, six bolts, suspended joints). They are ⅝-in. diameter and 6½ ins. long under the head, which is ⅝-in. thick. They pass through holes in the angle bars, the shank of the spike touching the edge of the rail base, and a cast washer between the angle bar and screw head giving a horizontal bearing to the head. Ordinary spikes are used on the intermediate ties, but it would be better to use the screw spikes throughout.

A neat arrangement of screw spikes, devised by Mr. Katte, Chief Engineer of the New York Central Ry., is shown at F, Fig. 33, and this has been put in use to a limited extent. The screws are of pressed steel, with cold rolled threads having a pitch of 4 per inch, and the clamps have a lip to bear upon the rail base, and a shoulder to receive the lateral thrust of the base. The upper surface is approximately parallel with the slope of the rail base, while the lower surface is horizontal. These clamps are rolled in bars and sheared to length. The clamp has a slotted hole, permitting of a lateral movement of ½-in. in either direction to provide for adjusting the gage without removing the screw, and a thin steel washer between the spike head and the clamp prevents the edges of the spike head from interfering with the edges of the holes. A hole is bored in the tie with an auger of a diameter equal to that of the screw at the root of its thread, the hole being at right angles to the upper face of the clamp. The holes are bored by hand augers, the auger-boring guide consisting of a vertical board, with brackets at the bottom to hold it upright, and having one edge cut to the slope of the spike hole. The bottom of this board is placed against the edge of the rail base, and the exact point is thus fixed automatically for starting the hole at the proper distance from the rail base and at the proper angle. The cost would be about 15 cts. per set for 1 tie, as against 4⅜ cts. for 4 ordinary spikes. If screw spikes were in general use the amount of maintenance work now required for driving down loose spikes would, of course, be greatly reduced.

On many railway bridges in other countries, T-rails are secured to longitudinal timbers by screw spikes placed against the rail base, or through holes in the base, the spikes being at such an angle that the head bears directly on the sloping upper surface of the rail base. The holes are drilled by crank augers, without the use of guides, and the spikes are screwed in by socket wrenches.

Bolts.—Bolted clamp fastenings of various styles are extensively used abroad, but in this country practically the only application is in the Bush interlocking bolts, Fig. 34, which are used to some extent on bridges

and trestles, and sometimes at supported joints and on curves. Bolt holes are bored with an auger at an angle of about 45°, intersecting under the rail, the proper position and angle of the holes being given by a boring gage, or guide, clamped to the rail. Each bolt has a part of the shank cut away, and when driven home the bolts are turned so that they interlock, each bolt then pulling against the other. The iron clamps which bear upon the rail base have slotted or oval holes, so that by loosening one nut and tightening the other, the clamps and rail may be moved sideways, so that the gage and line of track can be closely adjusted and maintained. The bolt A is first driven, and then bolt B. The nut of A is then screwed up until the shoulder C comes in contact with the shoulder D on bolt B. The nut on bolt B is then screwed up until the shoulder E bears against the shoulder F of bolt A. To remove the fastenings, the nuts are taken off, and bolt A is driven down a little, so that bolt B can be withdrawn. This makes a very secure fastening, and the cost is about 32 cts. per tie (4 bolts, 4 nuts and 4 clamps). It is

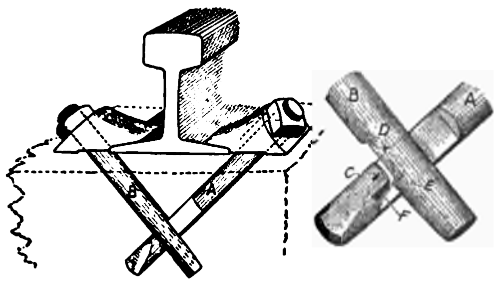


Fig. 34.—Rail Fastenings; Bush Interlocking Bolts.

said that one man can put in from 50 to 70 pair (25 to 35 ties) per day, or three men can put in 500 pairs (250 ties) in 2½ days. The bolt fastenings for steel ties on the New York Central Ry. are shown in Fig. 24.

In English practice fang bolts are largely used, the head of the bolt bearing upon a clamp or directly upon the rail base, while the threaded end passes through a large nut under the tie, this nut having fangs or projections to bite into the wood and prevent the nut from turning as the bolt is screwed down from above. In the author's paper on "The Improvement of Railway Track" (Transactions of the American Society of Civil Engineers, March, 1890), it was suggested that a better plan would be to have the head of the bolt underneath, using a fang-washer with ribs to prevent the turning of the bolt as the nut is screwed on, as shown at A, Fig. 20. A still simpler plan would be to have the fangs on the corner of the bolt head, which is quite practicable. Renewals of any through bolts are somewhat difficult, ballast having to be cleared away to allow a man's hand to get at the nut, washer, or bolt, but such renewals are, of course, much less frequent than with spikes. On some foreign tracks economy is effected by using spikes and bolts on alternate ties.

Rail Braces.—The lateral thrust on the rails at curves, turnouts, etc., is very severe, and the outer spikes are generally reinforced by iron or steel rail braces, which are spiked to the tie and bear against the side of the rail, thus taking the outward thrust. Guard rails and the lead rails of

turnouts are also reinforced by braces. Unless the braces are well designed and well looked after, their value will be very considerably reduced by the outer edge of the rail base cutting into the tie, throwing the weight on the top of the brace, and tending to raise its heel. To prevent this, a combination tie-plate and rail brace has been designed, its shape resembling that of the box brace in Fig. 35, but having the sides cut away at the bottom, and the base plate extended in front for the rail to rest upon it. The Weir box brace illustrated is of pressed steel, ¼ to 5-16-in. thick, and supports the rail head from below as well as at the side. The "box" fits over the rail spike. This is made by the Weir Frog Co., of Cincinnati, O. Another form of rail brace, made by the Ajax Forge Co., of Chicago, is shown on the right of Fig. 35. Steel is preferable to iron for rail braces, as the latter are liable to be broken in spiking, and are often made too light and too rough to give proper service. Almost any form of metal tie-plate will give increased safety and economy by preventing the cutting of the tie and the tilting of the rail, and such plates are now often used instead of rail braces. The ordinary braces do not prevent this cutting, so that the rail may be held merely by its head bearing on the brace, thus displacing the brace, and the rail thus often getting away from the proper support of the brace.

Rail braces should be used on all curves of over 8°, the number of braces to each rail increasing according to the sharpness of the curve. The Louis-

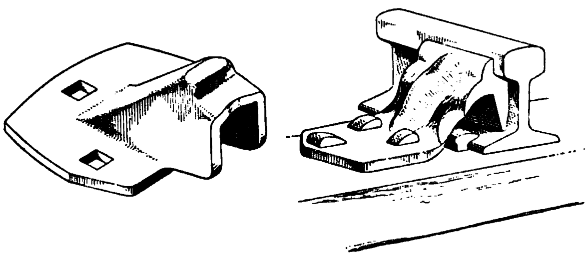


Fig. 35.—Rail Braces.

ville & Nashville Ry. requires the use of two braces on every fifth tie of 4° curves, on every fourth tie of 5° curves, and on every third tie of 6° curves, the braces being outside each rail and on the same ties. The Illinois Central Ry. specifies three braces to each rail on curves of 4° to 5½°; four to each rail on 5½° to 8° curves, and braces on every other tie for curves over 8°. Some roads specify three braces (at center and quarters) per rail on 5° curves with oak ties, and on 3° curves with cedar or other soft ties. Sometimes only the outer rail is braced, but more commonly both rails are braced, so as to resist the thrust on the inner rail due to slow heavy trains, and also to relieve the outside spikes of the inner rail from the lateral pull of the tie due to wheel pressure against the outer rail. Guard rails at frogs should have two or four braces, according to length, unless these rails are clamped or bolted to the track rails. The Roadmasters' Association of America, in 1895, adopted a report recommending (where tie-plates are not used) a rail brace of malleable iron or soft steel, about 8 ins. long, so made as to allow for reasonable shimming without pulling the spikes from the brace, and to fit perfectly against the under part of the head and web of the rail.

Check Plates.—These plates are used to prevent creeping of the rails on the ties, and have been described at the end of the chapter on "Rails."

Rail Joints.

The rail joint is as important a detail of the track as is the rail fastening, and has received very much more attention, for while weak joints are perhaps no more dangerous than insecure fastenings they cause a roughly riding track, and a more apparent wear of the rails, the economical necessity of providing against which is more in evidence than that of the effects of weak fastenings. A considerable part of the trouble with ordinary joints, however, arises from the too general tendency to purchase a cheap material. Then again, whatever kind of joint is used, good results cannot be expected unless it is properly looked after. In fact, a better track will probably be maintained where the foreman is a little bit anxious about the joints, than where he has new joints which he considers can be left to look after themselves. A good joint, however, properly looked after, will require much less expense and labor for maintenance.

The difficulty of making and maintaining an efficient joint will be understood if its work is considered. It has to hold together, vertically and horizontally, the free ends of two independent rails, the ends being subjected to very varying strains. At one extreme are the strains due to fast trains drawn by engines with driving wheel loads of 7 to 10 or even 12 tons per wheel, followed by a series of rapid blows from car wheels carrying 4,000 to 8,000 lbs. each, causing both shock and vibration. At the other extreme are the strains due to slow heavy freight trains, drawn by ten-wheel and consolidation engines having 3 or 4 driving wheel loads of 30,000 to 40,000 lbs., acting as slow pressures, and followed by 120 to 200 car wheels with loads varying from 3,000 to 10,000 lbs. per wheel, aggravated by flat or worn wheels. The heavy pounding of the slow heavy pressures, and the sharp strokes of the rapid hammer-like blows indicate what the joint has to stand, and why it has been given so much attention and still continues to give so much trouble. For a perfect joint and a smooth riding track, the splicing must be such as to make the joint as strong and as stiff as the solid rail, and also as elastic, so that it will return to position after the inevitable depression or deflection caused by the loads, and so carry the wave motion of the rail uniformly along the track. Few if any joints have yet thoroughly met these requirements, and the effect of the loading is, therefore, to cause the rail ends to eventually take a permanent set, and also to cause the parts to become loose. A very large proportion of the work of maintenance is thus, on most roads, expended in tightening bolts, raising low joints, and other work at this part of the track. One great difficulty with the joint question, however, has been too much effort to keep down the cost, and too little effort to keep up the quality, a remark which applies to many other parts of track work. If the joint and rail are of equal strength and flexibility, the wave motion will follow on evenly with an unbroken curve. If the joint is stronger or stiffer than the rail, the curvature under wheel loads will be checked by the joint, while if the joint is weaker or less stiff, then the rail ends will be depressed so as to form an angle or a curve so sharp that the wheels cannot touch the extreme ends of the rails. In either case the rails will become kinked and worn.

If we take a rail as a beam of given span, fixed at both ends and loaded in the middle, and cut it in two under the load (as at a joint) we get two beams of half the span, fixed at one end and loaded at the other, each carrying half the original load. The deflection of these two beams, carrying the same total load, is nearly ten times that of the original beam. The strength of the rail itself counts for little at the joints, and does not suffice to distribute the load over a great number of adjacent ties, as it does at the middle of the rail. The joint ties therefore have to take practically the whole impact of the load, unaided by the rail, and hence they sustain loads at least twice as heavy as those at the middle of the rail, besides being subjected to a rocking or pumping motion. It is for this reason that the joint ties go down more than the other ties, and it is the jumping of the wheels over the deflected rail ends, and not the jumping across the trifling expansion space between the rails, which causes the great wear at the joint. This wear is greater just beyond the joint, in the direction of traffic, and on single track roads a greater depression of the rail surface may be found on each side of the joint than at the joint itself. Investigation and experiment have shown

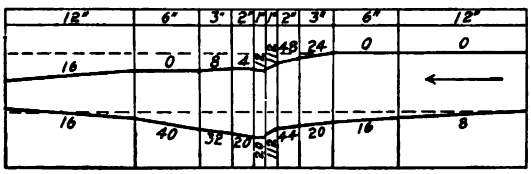


Fig. 36.—Diagram of Rail Joint Deflections.

that the wheel, in spite of the spring and the vertical play, has not time to follow the deflection of the rail ends, but jumps the depression (especially as the curves are convex) and strikes the entering rail a few inches back from the end, causing the rail to wear or "cut out" at that point. To this action is due the bulk of the pounding, noise and wear at joints

Experiments on the shocks to rolling stock caused by the gap alone have been made, and some were made in Germany in 1892. On a side-track in good condition, notches were cut in the rail heads at points directly over the ties, being 0.12-in. deep and 0.6 to 1.2 ins. wide. Trial runs with a locomotive and inspection car were made over the section thus prepared, and noticeable shocks were experienced by the observers on the engine only with the notches 1.2 ins. wide, while observers stationed along the track could scarcely discern the special noise produced by the passing wheels. Increase of speed seemed rather to diminish the noise and magnitude of the shocks. The rails, of course, could not deflect at the notches. Investigation of the deflections of rail joints have been made by Mr. Anthony, and Fig. 36 shows one case, plotted to an exaggerated scale. The lines show the grades for 2 ft. on each side of the joint, the upper line being for 80-lb. rails on gravel ballast, after 6 months' service, and the lower line showing older and lighter track. The diagrams show that the end of the entering rail tends to be permanently depressed, having a flatter up-grade to the normal level than the

leaving rail. With lightly loaded wheels the deflection will not be so great but that the wheels may touch the whole rail, but under heavily loaded wheels the deflection will be so great that the wheels (especially at high speeds) will not touch the extreme ends of the rails, but jump across and strike the entering rail a little distance back from its end. The drop at the gap itself will be almost imperceptible, for the versed sine of half the angle which has for its radius the radius of the wheel and for its chord the width of the gap, is exceedingly small. With a 33-in. wheel and a gap ½-in. wide, the drop of the wheel and axle would be only 0.002-in., and with a gap of 1-in. only 0.008-in. The drop at a gap of ⅜-in. would be as follows: 30-in. wheel, 1-170-in.; 36-in., 1-210-in.; 60-in., 1-300-in.; 72-in., 1-360-in. In general, the gap should not exceed ⅜-in. at 0° F. for 30-ft. rails, while ⅝-in. has been advocated for 60-ft. rails.

Miter Joints.—The idea that the gap of the expansion spacing caused the shock led to experiments with miter or bevel joints, which were used as early as 1816 and 1824. In 1867, Mr. R. H. Sayre, then Chief Engineer of the Lehigh Valley Ry., began experiments in this direction, cutting the ends of the rails at angles of 45 or 60°, and this practice was followed on that line from about 1869 until 1895, when it was abandoned, as a number of rails broke close to the end, the crack starting at the junction of the head and web, extending back about 3 ins. and then running up to the top of the head. It was also tried on the New York Elevated Ry., with Fisher joints, but was given up. Some persons have thought that they saw some good from it, due probably to the joint being better made in other ways, but it is hardly possible that any real and sensible benefit due to the miter cutting in itself can ever have been observed, as this plan is based upon the false theory that the jolt to the car wheels comes from the little gap or break in the continuity of the rail surface, whereas it comes from the elastic yielding of the rail ends, which is not helped in any way by the mitering of the rail ends. The Lehigh Valley Ry. track with miter joints was very easy riding, but this was undoubtedly due in large part to the stiff and substantial splicing. The committee of engineers appointed in 1894 to report to the General Managers' Association of Chicago, on the use of long rails, recommended cutting the rail ends on a bevel of 45° to 60°, but it is difficult to see how such a recommendation was arrived at.

Scarf Joint.—This is the revival of another old plan, and seems at first to be a modification of the miter joint. The two rail ends are halved or scarfed, placed side by side, and bolted together, the bolts passing also through the spliced bars. As used on the Prussian State Ry., the rail ends are scarfed for about 8½ ins., and have 26-in. splice bars, with 4 bolts spaced 5, 4, and 5 ins. c. to c. The two middle bolts pass through both rails and both bars. In the ordinary form the strength of the joint is diminished by the thinness of the web and the lack of fit of the bolts, but to avoid the necessity of planing away half the web, Dr. Vietor, of Germany, has designed a rail with its head not set centrally over the web, so that only the rail head need be planed away at the scarf, leaving both webs of full section side by side. If this joint was put up like a riveted connection, or with tightly fitted bolts, it would be very stiff, the rail ends supporting each other, but as the bolt holes must be large enough to admit of expansion, it is helped only by the friction of the webs, depending upon the tightness of the bolts.

Splice Joint.—The early T-rails had the ends resting in iron chairs on the ties, the chairs having lugs to fit over the rail base. As there could be no tight fit, and the chairs were often very rough, there was a jarring and violent motion of the rail ends which caused a clattering noise and the breakage of chairs and rails. The flat splice-bar or fish plate was invented in this country in 1830 by Colonel R. L. Stevens, for the Camden & Amboy Ry., as shown in Fig. 26, and it was reinvented in England in 1847 by Mr. W. Bridges Adams. The pear-shaped T-rail could not be efficiently spliced with fish plates, as the pressure on the rail tending to depress the joints wedged the plates apart, and the bolts thus soon became loose. With the modification of the rail section, however, to practically its present form, with fishing angles of about 13°, and a high vertical web, this joint became more practicable, and began to come into use about 1855. This type, including its development into the use of angle bars, is now practically the standard throughout the world. It consists of two flat (or angle-shaped) bars, bearing against the underside of the rail head and top of rail base, and held together by bolts passing through the bars and the web of the rail. In order to increase the strength the angle bar was devised, first rolled about 1868 or 1870, having a vertical web like the fish plate and an inclined or horizontal flange extending over the rail base. The angle bar joint is now the almost universal type of first-class track in this country, and is likely to continue to be the standard type for roads with comparatively light track and light traffic. For first-class track, however, it will probably be supplemented by a base support to the rails (as noted below), to form either a supported or a bridge joint.

Angle Bars.—In some of the older joints the outside bars extended along the side of the rail head, but this practice has now been almost entirely abandoned as being unnecessary. The bars should be so designed and proportioned as to make the joint as strong and stiff as the body of the rail, in which particular very many joints now in use are defective, more especially as to the stiffness to resist slight deflections. The horizontal flange of the bar adds to the lateral stiffness of the joint and keeps the track in better alinement. The base of the flange is usually level with the base of the rail, thus giving additional bearing in the tie, but many roads use a bar in which the flange is purposely kept above the tie to prevent such bearing, though this practice is not to be recommended. The flange is usually wide, but sometimes it extends only about ⅝-in. beyond the rail base, barely enough to give a good hold for the slot spikes, as at B, Fig. 37, and at Fig. 39, which spikes may be crowded out by a creeping track. It is much better to have wide flanges with deep slots for the spikes to prevent creeping, while with holes in the flanges all the spikes resist motion in every direction, and the gage is more permanently maintained.

The bars are usually of uniform section throughout, but sometimes have the thickness of the web increased at the middle (where fracture usually occurs) by tapering from the ends, or by offsets as in the Samson bar. The sections of splice bars vary very greatly, as shown in the illustrations, but one of the best is the Sayre section, shown at Fig. 27. The heavy top chord makes an exceptionally stiff bar, with great bearing surface for the rail head. The bars are very generally too soft, however, having only about 0.1 to 0.25% carbon, and much better results would be

obtained with steel having 0.3 to 0.4% carbon, while some foreign railways specify the same steel for rails and splice bars. In many cases where it has been desired to increase the strength of angle bars, the change of design has been mainly in increasing the thickness of the web, coupled sometimes with increasing the vertical thickness of the flange at its junction with the web. In the Dudley angle bar sections, the metal has been distributed with a special view to stiffness, the web being even thinner than usual, but the bars are of steel with 0.4% carbon, which is hard and tough to resist wear. The section is stiff, but has sufficient elasticity to make it give long service before taking a permanent set, and the web is thin enough to stand clean punching, without deformation or warping. This type is shown at A, Fig. 37, which is the bar for the New

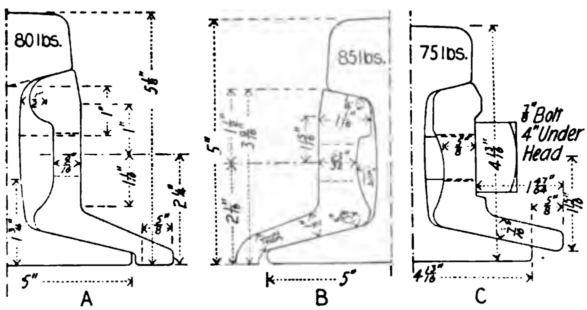


Fig. 37.—Sections of Splice Bars.

York Central Ry. 80-lb. rails. At B, Fig. 37, is the thick, but narrow flanged splice bar of the Pennsylvania Ry., while at C is shown the angle bar of the Chicago, Burlington & Quincy Ry., which has no rib on the edge of the flange. In some cases the flanges of the angle bars are kept clear of the tie, as in Fig. 39 and C, Fig. 37, but the better and more common practice is to give a good full bearing on the tie as in Figs. 27 and 30, and A, Fig. 37.

One of the bars usually has square, oval or kite shaped holes to fit the neck or body of the bolt, and prevent the bolt from turning, while the other has round holes just large enough to clear the bolt. The hole should be of such size as to require a smart tap on the bolt to send it home, the larger holes in the rail ends allowing for the expansion and contraction of the rails. On the Memphis Bridge, the splice bars have holes into which the bolts go with a driving fit, the holes in the rail being ¼-in. larger. In this way the two bars become practically one member, and good results have been reported. If the bolts have L heads bearing on the flange of the bar, or T-heads used in conjunction with grooved bars, both bars may be drilled or punched alike. With thick bars it is almost impossible to prevent them from getting out of true when punched, and if they are put in the track in this condition the efficiency of the joint is materially impaired.

This form of joint is an excellent one, simple and easily made, and keeping track in good line, while its efficiency has increased with the in-

crease in depth of modern rails. When the bars are once notched or bent, however, the joint deteriorates rapidly, as it is almost impossible to restore the bar to proper line. To take up the wear at the top of the bar right at the ends of the rail (which wear at once reduces the efficiency of the joint) some English railways use an iron washer between the rail and bar at this point. There is also a patented device consisting of a thin renewable bearing piece or liner between the rail head and splice bar. It is not economy to keep in service bent, worn or crooked bars, as they lead to wear of the rails and injury to track. In foreign practice it is very common to use bars of Z-section, having two vertical webs, the lower webs projecting below the rail and having sometimes bolts through them, causing the flanges to grip the rail base. The Cloud joint is of this pattern, but would be better if used with a base plate, as in the Churchill joint of the Norfolk & Western Ry., described further on. Bars of this section, without the lower bolts, are used in other countries for T and bull head rails, and for the lattter rails the bars are sometimes bent to fit round the lower head.

Breakage of Angle Bars.—The irregular manner in which splice bars fracture is due to the very varying conditions of load and support. The ties may be loose from the rail or loose from the ballast, and the transfer of the load from one rail to the other effects a reversion of strains in the angle bar at each wheel passage. Breaking of the angle bars from the bottom is very often due to carelessness in raising track, the joints being raised too high before the centers or quarters of the rails are raised, instead of maintaining a proper surface in raising. When there is a wheel on each side of a supported joint, the tendency is to throw the joint up, putting a tension strain in the top of the bar. With a suspended joint, the bars get a downward deflection at the middle, and when the joint is raised the bars get a tension strain in the top. In regard to the wear and breakage of joints, it has been already shown that the entering rail gets a severe blow from each wheel a few inches back from the end, which tends to loosen and drive down the shoulder tie (of a suspended joint) if it is not kept well tamped. If this tie is allowed to sink in the ballast, the angle bar gets a tension strain along the top as each wheel passes, and if the tie is tamped up again, and again allowed to become low, the bar will eventually crack from the top. This may be prevented to some extent by lengthening the angle bar, though the ends of very long bars do but little effective work. Under normal conditions, with well tamped shoulder ties, the bar should crack (if it does crack) from the bottom. Broken angle bars should be replaced at once, and the track examined to ascertain the cause of the breakage.

Supported, Suspended and Bridge Joints.—There are three general plans of arranging the joints, as follows: 1, supported joints, in which the rail ends rest upon a joint tie; 2, suspended joints, in which the rail ends project beyond the shoulder ties and are supported entirely by the splice bars; 3, bridge joints, in which the rail ends project beyond the shoulder ties but are carried by an iron or steel bridge plate or base plate whose ends rest upon the shoulder ties. The supported joint was necessarily used with chair joints, and when splice-bar joints were used, it was at first believed better to give a support to the rail ends, to enable them to withstand the blows from the wheels, but as wheel loads increased it was found in

practice that with the usual spacing of ties the joint tie did not give sufficient support, and if tamped up hard enough to prevent its sinking in the ballast under the traffic it was too rigid a support, forming an anvil upon which the rail ends were battered, while the wave motion was not carried along uniformly and the track was likely to be a rough riding one. A modification, however, is the three-tie joint, in which two shoulder ties are placed close to the joint tie, and the angle bar is made long enough to extend over the three ties. This has been introduced on a number of railways, and is considered to give very good results under fast and heavy traffic. The opponents of this type of joint argue that the three ties are too close together (6 to 8 ins.) to allow of proper tamping, and that by lack of uniformity in tamping one of three conditions will occur: 1, the joint tie will be more tightly tamped, making a supported joint with a long span between the shoulder ties; 2, the shoulder ties will be the more tightly tamped, making a long and weak suspended joint; or, 3, the third tie (or the shoulder tie of the entering rail) will be loosened by the jump of the wheels at the joint, and will thus cause the splice bar to be bent down, which with the reaction of the rail ends as the load is removed will crack it from the top. Practical experience on the New York Central Ry., however, does not appear to sustain these arguments. The suspended joint distributes the load over the two ties, and, if the fastenings are strong enough, it makes a better provision for the deflection and wave motion. It is by far the most commonly used. The ties should be about 8 or 10 ins. apart. Fig. 38 shows the construction of the three-tie joint of the New York Central Ry., and Fig. 39 shows that of the suspended joint of the Lake Shore & Michigan Southern Ry.

Bridge Joint.—This type of joint is coming more and more into favor, and appears to be based on the most correct principles, especially for main tracks with heavy traffic, and it combines a base support with the necessary elasticity, providing that the base plate is not made too heavy and stiff so as to form an anvil. The rail ends should invariably be securely bolted to the plate to make it act with the rail ends and to prevent clattering. Several forms of bridge joints are shown in Fig. 40, and one of the oldest and best known of these is the Fisher joint, which has a slightly

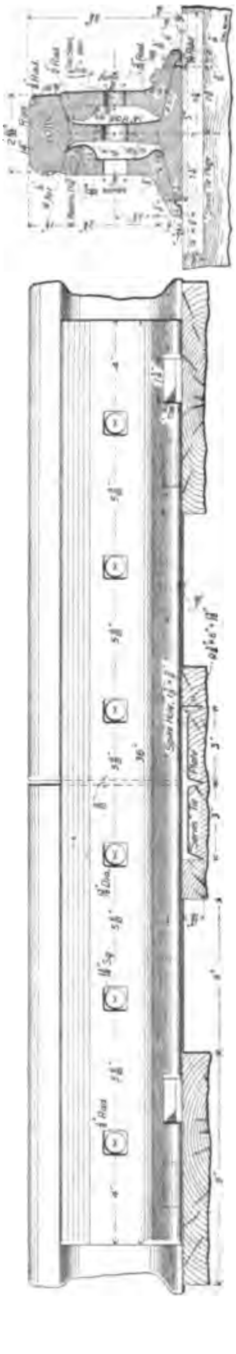


Fig. 38.—Three-Tie Rail Joint; New York Central Ry.

cambered "bridge" plate, with its ends resting on the shoulder ties, to which the rails are held by a U-bolt whose vertical ends pass up through the bridge plate and through notches formed by clipping off the corners of the rail base. A curved steel spring plate between the underside of the bridge plate and the horizontal leg of this bolt puts sufficient tension to prevent the nuts from slacking loose. In the older form of the joint the rails were held only by clamps through which the legs of the U-bolts passed, and upon which the nuts were screwed down. To meet the objection that this did not afford sufficient lateral security, the joint is now made with two short angle bars, the web being long enough for two bolts, and the flange only long enough to act as a clamp held down by the nut of the U-bolt. The flanges bear against ribs on the edges of the bridge plate, which prevent any lateral motion. The webs do not extend up to the rail head, as Mr. Fisher considers that in view of the base support they are only required to act as a splice for the rail ends. An objection sometimes made against bridge joints is that the shoulder ties must be adzed down or placed lower in the ballast, and if the latter plan is adopted with track laid with broken joints the surface of the ties will not give a proper bearing for the rail.

Several railways are now using bridge joints of their own design. The Chicago & Northwestern Ry. joint for 80-lb. rails has the rail ends resting on a grooved plate 24 ins. long, spanning between the joint ties. The defect of this is the absence of bolts to hold the rails or angle bars to the plate, but still the joint makes an easy riding track. A better joint is that of the Chicago, Burlington & Quincy Ry., designed by Mr. Delano, who believes that the rails should be firmly bolted to the plate, which should act merely as a long washer to prevent independent action of the rails'

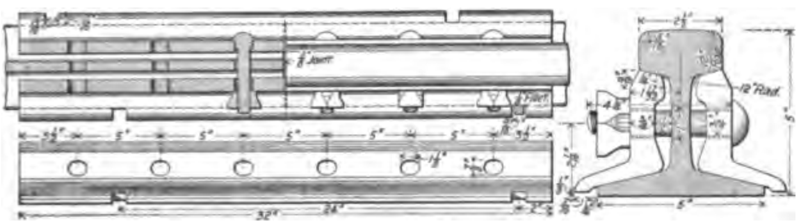


Fig. 39.—Suspended Rail Joint; Lake Shore & Michigan Southern Ry.

ends in deflection. In this joint the 12-in. angle bars bear on the head and base of the rail in the usual way, and are bolted to the base plate by four bolts. A majority of the modern designs of joints are of the bridge type, and among these may be noted the Continuous, Heath, Price, Truss and Weber joints. The Continuous joint consists of two angle bars with wide flanges bent round to fit under the rail and form the base support, each bar extending under nearly half the width of the rail base. The ends of the bars rest upon the shoulder ties, and the edges are slotted for spikes. The bars are of low carbon (0.1%) steel, and for 70-lb. rails they have a web 9-16-in. thick; flange, ⅝-in.; and base 7-16-in., which latter should be heavier. They may be of any desired length, but short bars with four bolts are considered best. The Heath joint consists of a plate 11 × 24 ins., and ⅜-in. thick, bent to form an angle bar and bridge plate, the full width

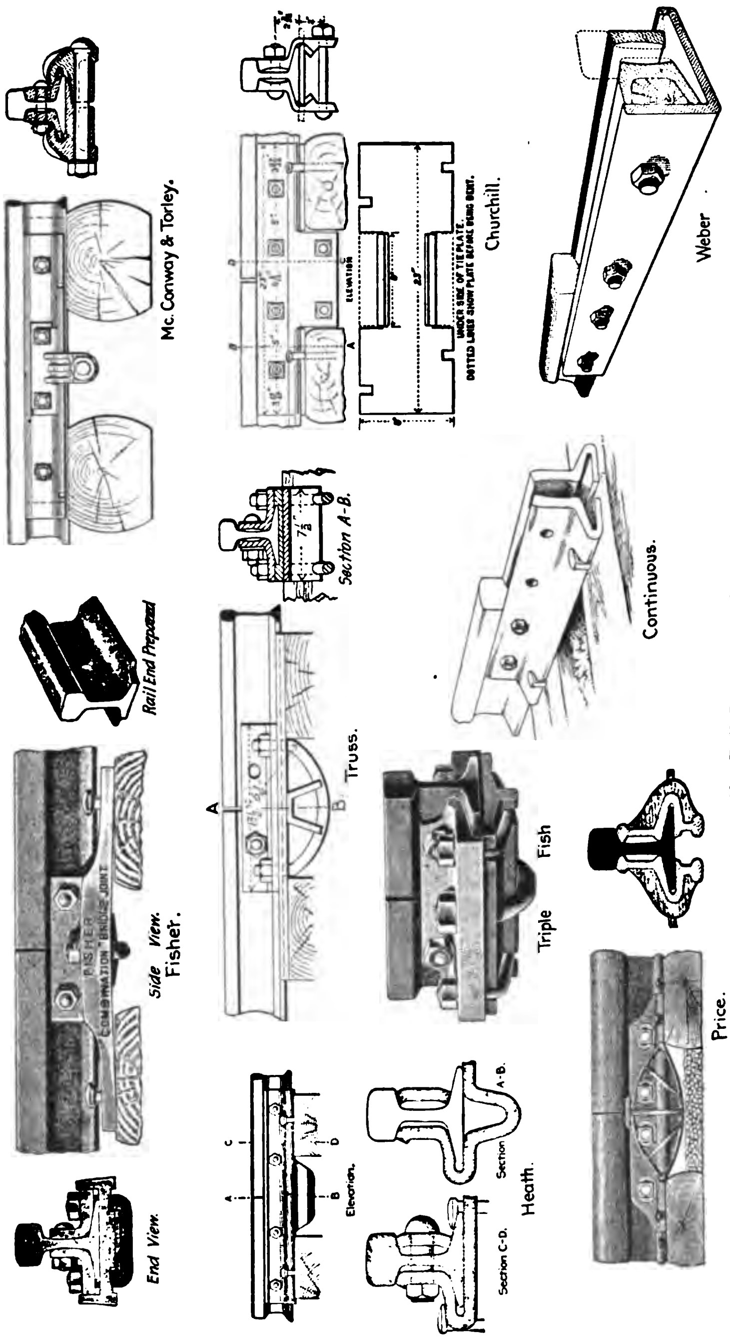


Fig. 40.—Rail Joints of Bridge Type.

of the rail base, the ends resting upon the joint ties, while the middle is dished to form a pocket which gives stiffness under the rail ends. On the inner side of the rail is a flat splice bar. Four ordinary track bolts are used, and spikes are driven through the projecting inner edge of the bridge plate to prevent creeping. The main plate is of low carbon (0.1%) steel, and is heated in oil ready for being shaped under a steam hammer and punched for the bolts.

The Churchill joint used on the Norfolk & Western Ry. has a bridge plate 23 × 8 ins., 9-16-in. thick, with the sides bent down for 8 ins. at the middle to bear upon ribs on the splice bars, which bars are 23 ins. long, and have vertical webs 8 ins. deep projecting below the rail and engaging with the notches in the bridge plate. Two ¾-in. bolts pass through these lower webs, and four ¾-in. track bolts (5, 5 5-16 and 5 ins. c. to c.) through the upper webs and rails. The cost of maintenance is found to be 50% less than with angle-bar joints on the same part of the road, while the track is in better condition where the bridge joints are used.

The Price joint has two malleable iron or cast-steel bridge plates, on edge, each having a groove tightly gripping the edges of the rail base, and not supporting the rail by its head. The plates are held together by bolts through or under the rails. The Truss (or Long) joint has a bridge plate resting on the ties, and underneath the middle of the plate is a transverse piece of V section, supported by two long U-bolts parallel with the rail. The threaded ends of the bolts are secured by nuts on the flanges of the angle bars. These bars are 13½ ins. long, with two bolts through the rails, and they do not touch the rail head. The Weber joint has an L-shaped bridge plate, with a web as high as the rail web. This web is on the outer side of the rail, and a channel-shaped splice bar is placed against the rail, with a wooden filling strip between the bar and the web of the bridge plate, while an angle bar or fish plate is used on the inner side of the rail. Four track bolts are used. The wooden strip is not a commendable feature of the joint.

Base Joint.—This type of joint has a base support between the shoulder ties, but not resting upon them to form a bridge, as shown in Fig. 40. One form of the Fisher joint is made in this way, the base plate being secured by vertical bolts or transverse U-bolts to the angle bar and rail base. The McConway & Torley joint has two jaws which grip the edges of the rail base and angle bar, and extend under the rail, one jaw passing under the other, and both having inclined surfaces, so that as the one transverse bolt through the jaws (under the rail) is screwed up it induces an upward thrust upon the rail ends, while also wedging the jaws upon the angle bars. The Creighton joint has a 12-in. piece of rail inverted under the joint and secured by two double-web splice bars, with four bolts through the upper webs and track rail, and two bolts through the lower webs and base rail.

Hinge Joint.—It is of the utmost importance to hold the ends of the rail heads in the same horizontal plane or curve, so that they will rise and fall together during deflection. For this reason the ideal joint would be a hinge, and a hinge joint has been actually tried in India. This has five bolts, the middle bolt passing through notches in the ends of the rail webs, but the lack of fit between the bolt and the rail, and the small bearing upon the bolt, prevent this from having its full theoretical value. The

fish plates are 9½ ins. long, with bolts spaced 4 ins. apart, and weigh 27½ lbs. per pair. This joint is used on 75-lb. T-rails, and would probably be improved, for heavy traffic, by a bridge plate. Hinge joints have been devised with the rail ends dovetailed or interlocked, but the expense and difficulty of shaping the rail ends preclude their use.

New Joint Devices.—Besides the special joints above described there is a great number of patented joint devices, many of which are entirely impracticable and useless. Several of the more practicable designs have been tried, generally to a limited extent, and where tried in regular service they have usually been found to be no better than an ordinary good angle bar joint. The investigation of the results from various forms of joints is a difficult matter, as in many cases new joints are put on with new rails or when the track is surfaced, and the joints are assembled with more care than is ordinarily given. Any improved results are then usually attributed to the efficiency of the joint device, when they are really due to the greater care in assembling and track work. A good angle bar joint, put on with equal care, would show perhaps even better results than the experimental device.

Broken or Even Joints.—The rails may be laid with joints opposite one another, or with the joints on one side opposite the middle of the rails on the other side. The latter arrangement is the better, and the most generally approved, as it makes better running track, with less maintenance work for surface and line. It also helps to maintain the alinement, as with even joints (especially with fish plates instead of angle bars) there is a tendency for the rails to form angles or kinks at the joints. With even joints the pounding is more severe, while with broken joints the solid rail on one side takes a part of the axle load and shock, as shown by the bright spot of wear opposite the joint. These remarks, both as to wear and maintenance, apply to light and heavy track, with good or bad ballast. It is frequently assumed that even joints are better for light track with poor ballast, but this is incorrect, and they require more maintenance work to keep them in condition, which is serious on a road with light traffic and a limited track force.

Length of Bars and Spacing of Bolts.—There are very varying opinions held as to the length of splice bars and the spacing of the bolts, and for all the various arrangements good results are claimed. As a matter of fact, probably any style, well maintained, will give good service, but the amount of metal and of maintenance work must be taken into consideration. The bolt hole spacing ranges from 4 to 12 ins., but the very wide spacing is objectionable, and it is advisable to get center bolts as near to the ends as possible, while still leaving metal enough to ensure against cracking or fracture. The length of bars is from 20 ins. with four bolts on the Boston & Albany Ry., weighing 45 lbs. per pair, to 48 ins., with six bolts, on the Lake Shore & Michigan Southern Ry. and Savannah, Florida & Western Ry. The logic for the very long bars is hard to see, especially where the bolt holes are several inches from the ends, as the metal beyond these holes does little service. The present standard of the Lake Shore & Michigan Southern Ry. is a 32-in. bar with six bolts. The old 36-in. splice bars of the Concord & Montreal Ry. had four bolts 6 ins. c. to c., leaving 9 ins. free beyond each of the end bolts. The best lengths appear to be 20 to 24 ins. for supported joints, 24 to 30 ins. for suspended

and bridge joints, and 36 to 40 ins. for three-tie joints. Table No. 8 gives a number of joint arrangements:

TABLE NO. 8.—RAIL JOINTS.

Railway.	No. of bolts.	Length of bar, ins.	Spacing c. to c. of bolts. Middle, ins.	Intrmd, ins.	End, ins.	Joint.	Weight of rail, lbs.
Sav., Fla. & West.	6	48	6	12	6	3-Tie.	75
Lake Sh. & Mich. So. (old)	6	48	6	6	11	Susp.	70
Canadian Pacific	6	44	5¼	6½	9¾	3-Tie.	72
Erie (old)	6	40	8	6	7	Susp.	80
Fall Brook	6	40	5	6½	8	3-Tie.	75
New York Central	6	36	5.6	5.6	5.6	3-Tie.	80-100
Southern Pacific	6	36	7¼	5	5	3-Tie.	76
Pennsylvania	6	34	4	5	6	Susp.	85-100
Lake Sh. & Mich. So. (new)	6	32	5	5	5	Susp.	80
Norfolk & Western	6	30	5 5-16	5	5	Susp.	85
Philadelphia & Reading	6	30	4	4	5	Susp.	90
Baltimore & Ohio	6	30	4	5	6	Susp.	85
Erie (new)	6	30	4 3-16	4¾	4¾	Susp.	80
Lehigh Valley	6	28	4	4	4	Susp.	80
Concord & Montreal (old)	4	36	6	..	6	Susp.	72
Quebec Central	4	30	6½	..	7	Susp.	60
Chicago Great Western	4	26	6	..	6	Susp.	75
Chicago & Northwestern	4	24	6	..	6	Bridge.	80
Grand Trunk	4	24	7	..	6	Susp.	79
Fitchburg	4	24	5	..	8	.....	75
New England	4	24	6	..	6	Supp.	75
N. Y., N. H & H.	4	24	5	..	7	Susp.	100
Southern	4	24	8	..	5	.....	70
Norfolk & Western	4	23	5 5-16	..	5	Bridge.	85
Boston & Albany	4	20	4¾	..	4¾	Supp.	95

Bolts.—Track bolts are now usually made of mild steel, and are ¾-in. or ⅞-in. diameter, a very few roads having them as large as 1-in. diameter for heavy rails, while ⅞-in. and 1-in. bolts are used for frogs. They are 3½ to 4¾ ins. long under the head, but should not project more than ¼-in. beyond the nut. They are put up in kegs of about 200 lbs. A keg contains about 250 bolts, ¾ × 3½ ins., with nuts 1¼-in. square; 208 bolts ¾ × 3¾ ins., with 1½-in. nuts; 221 bolts ¾ × 4 ins., with 1¼-in. nuts; or 195 bolts ¾ × 4¼ ins., with 1½-in. nuts. The bolts should be well made, straight and smooth, with well cut threads, and the threaded portion should be as short as possible, so as to give the body of the bolt a full bearing in the splice bar. The threads should be of U. S. standard, so made on both bolt and nut that the nut can be screwed on by the fingers only for the first three or four threads, after which it must be turned by the wrench, the fit being such, however, as not to burst the nut or strain the threads in screwing up with an ordinary track wrench. The bolt has usually an oval or kite-shaped neck under the head, fitting into a hole of corresponding shape in the splice bar, in order to prevent the bolt from turning while the nut is being screwed on or off. The length of the neck should be equal to the thickness of the splice bar. The Sternbergh bolt, Fig. 41, having the Harvey grip thread, as used on the New York Central Ry. and many other roads, is of mild steel and has the thread formed by a sort of cold rolling process instead of by cutting, the diameter at the root of the thread being the same as that of the shank, while in the ordinary bolt (like that of the Pennsylvania Ry., Fig. 41) the metal is cut from the shank and so reduces the thickness at the root of the thread. The Wrenshall oval-bodied bolts have been extensively used. Those on the Northern Pacific Ry., Fig. 41, were ⅞ × 11-16-in. in the body, and 1 × ¾-in. in the neck, with a head of 1 7-16-ins. diameter.

Track bolts usually have button or cup heads, but the head is often too

small and too thin at the edge, so that the wear on the edge is likely to soon reduce the bearing surface, especially as the contact surfaces are very often too rough for a good bearing. It might be better to use either a square or a T-shaped head, and if a grooved splice bar was used with these (as was the practice some years ago) or if an L or hook-shaped head was used, bearing on the flange of the angle bar, there would be no necessity for a neck on the bolt, and both bars would be drilled or punched alike.

The nuts should be well formed, with true and clean cut threads, and should be thick enough to give a good bearing surface, as the use of thin nuts results in loose nuts and damaged threads. Both square and hexagonal nuts are used, but the former are the better, and should be 1⅝ ins. square for a ¾-in. bolt. The corners are sometimes chamfered toward one face of the nut, giving a better hold for the wrench, as in the Ideal nut.

The bolts may be put on with the nuts on the inside or outside of the rail, but the former is the most approved practice for heavy track, though with light rails it is sometimes necessary to put them on the outside to be clear of the wheel flanges. While well made and fitted bolts and nuts have much less tendency to work loose than those which are cheaply and roughly made, a nut-lock is generally placed between the nut and bar to give a spring or elastic bearing to reduce the vibrations and prevent the nut from slacking. The Harvey lock nut, however, now largely used on heavy track, obviates the necessity for using a separate lock, and has thus an added advantage in reducing the number of parts of each joint, or saving 1,408 pieces for each mile of single track. The bolt has a ratchet thread, undercut on the bearing side; the nut has also a ratchet thread, the bearing side of which is at right angles to the axis of the nut. When the nut is screwed hard against the splice bar, the bolt threads are forced out into the nut threads, so as to fill them completely and make a tight fit. The nut has the bolt hole enlarged at the bearing face, forming a chamber to enclose and protect the bolt threads from the rubbing or pounding action of the angle bars under traffic, thus ensuring good threads to screw the nut upon when the joint becomes loose. The nut has a slightly varying thread, the thickness of face of thread and depth between threads increasing towards the outer ends of the nut by flattening the angle of the thread. When the nut is screwed up, the thread is upset on the thread of the bolt, securing a tight fit, especially if the bearing surfaces of the nut and splice bar are good. Mr. C. C. Wrenshall, formerly of the Northern Pacific Ry., said: "If you want the splices to hug the rail

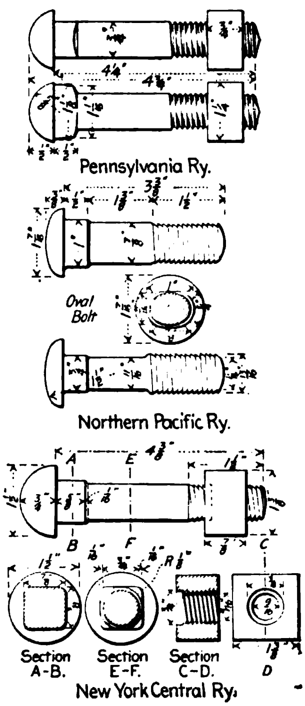


Fig. 41.—Track Bolts.

ends with a death grip during the passage of rolling stock, then avoid all elastic substances or springs; bolt up tight with a metal strain of about 10,000 lbs. per sq. in., and use the Harvey grip thread, so that the nut will be a tight fit and stay where you put it." A form of joint has been tried in which the bolts are tapped or screwed into threaded holes in the outer bar, and prevented from turning by a split key driven through a slot in the bolt. Track bolts are shown in Fig. 41.

Nutlocks.—Of the numerous nutlocks on the market and in use, the majority rely upon a spring action. Probably the most extensively used is the Verona, which is a steel split washer twisted spirally to give about ¼-in. opening. A blank is taken just large enough to make one nutlock, coiled on a mandril, tempered in lard oil, the temper drawn to the proper degree, and then tested by pressing it flat under a steam hammer, after which it must open ¼-in. There are many modifications of this nutlock, some formed by twisting, jagging or pointing the blank, so as to cut the softer metal of the splice bar, but this is by no means a good plan. The Excelsior single and double spring nutlock are extensively used, the latter locking a pair of nuts. The Davies nutlock is a steel plate somewhat longer than the space between the bolts, with its ends notched to fit over two adjacent bolts. The plate is cambered, and is put on with the concave side outward, the nuts being screwed down to bring the plate flat against the splice bar. Vulcanized rubber, protected between iron washers, has been largely used, but is going out of use as it deteriorates, becomes hardened by exposure, and loses its elasticity. Among the nutlocks which do not depend upon spring action may be noted the following: 1. The Stark nutlock has a keyway on the bolt and eight keyways in the nut, so that a keyway is formed at each one-eighth turn of the nut, a U spring pin being then slipped into the groove. 2. The Young nutlock is a thin oval nut or jam nut with the bolt hole at one end; after the track nut is screwed up the lock nut is run up to it, and the weight of the heavier end hold it in position so that it cannot work loose. 3. The Jones nutlock is a thin flexible plate or washer, the top of which comes against the under side of the rail head, and the lower end of which is bent up against the nut when the latter has been screwed home. 4. The Fougere nutlock is a jam nut with the thread tapped at an angle, so that the nut runs eccentrically upon the bolt and is bent flat by screwing it up against the main nut.

A lock nut which, like the Harvey, requires no separate piece, is the Elastic or National nut, made of spring steel cut from a bar and having the ends so shaped as to form a dovetail, scarf or halved joint when brought together by bending the flat bar into a ring. The rough ring is then pressed into hexagon shape, the height being reduced by the operation, and is then tapped slightly smaller than the bolt, so that when it is put on with a wrench it opens about 1-64-in. at its joint, and a clasp or grip upon the bolt is thus developed, as the fiber of the metal runs around the nut. If the ends at the joint are cut at an angle this initial opening of the nut will also set up a lateral pressure on the threads of the bolt. The nut can be slackened and tightened, and used over and over again, the grip causing no injury to the threads of either nut or bolt.

The Roadmasters' Association of America, in 1895, recommended a nutlock which will not catch in the bolt hole of the splice, will not rotate with the nut, will not injure the threads of the bolt or nut, and will retain its

spring after the nut is loosened. Whatever form of nutlock is used, it should be simple, strong, durable and permanent. Several forms are shown in Fig. 42.

Examples of Rail Joints.—The New York Central Ry. uses three-tie joints, Fig. 38 having ties 9 ins. face, 6 ins. apart, and splice bars 36 ins. long. On the middle tie is a three-flanged Servis tie-plate, 9¾ x 6 ins., 13-16-in. deep. The rail has 1-in. holes. One splice bar has holes 15-16-in. square, with rounded corners, and the other has holes 13-16-in. diameter. The spike slots are 1¾ ins. wide. The bolts have cold-rolled threads of the Harvey grip pattern; they are 4⅜ ins. long under the head, ¾-in.

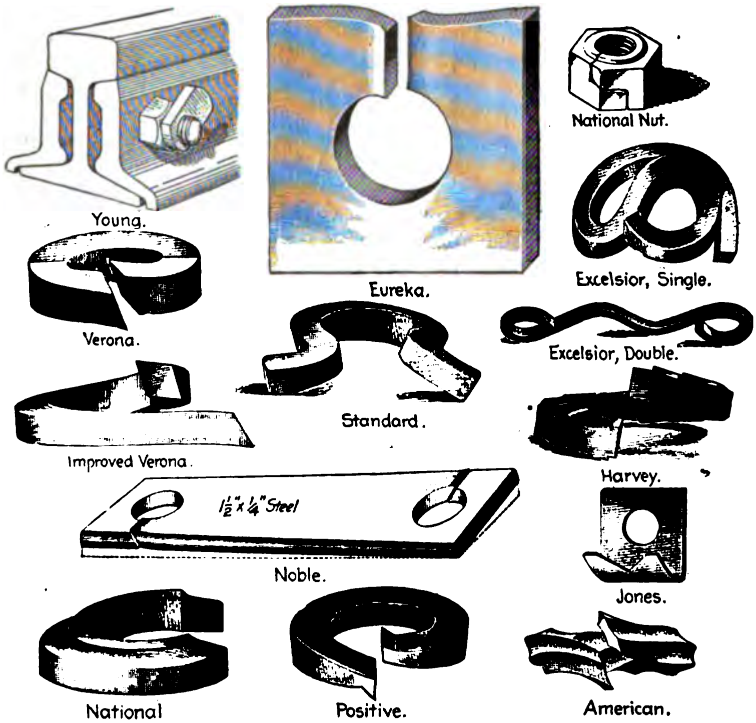


Fig. 42.—Nutlocks.

diameter, with neck ⅞-in. square having ⅛-in. rounded corners; the cup head of the bolt is ¾-in. thick and 1½ ins. diameter. The nut has the Harvey thread, and is 1⅜ ins. square, ⅞-in. thick. The old splice bars, shown in Fig. 38, have the flanges extended but little beyond the rail base, and coming down to within 1-6-in. of the tie. The new form is shown at A, Fig. 37.

The Lake Shore & Michigan Southern Ry. uses a suspended joint, Fig. 39, with 32-in. bars, and six bolts ¾-in. diameter. The spike slots are 13-16-in. wide and 1 1-16 ins. deep, with ⅛-in. filleted corners; these slots are 6 ins. and 2 ins. from the ends of the bar. The bolts are ¾-in. diameter, 4¼ ins. long under the head. The Boston & Albany Ry. has supported

joints with 20-in. bars weighing 45 lbs. per pair, and having four ⅞-in. holes, 4¾ ins. c. to c. The bolt holes in the rail are 1-in. diameter. The inner bar has a longitudinal groove to hold the bolt heads. The bolts are ¾-in. diameter, with double Excelsior nutlocks. Each splice bar has a 13-16-in. spike hole in the flange, the holes in the two bars being 1 in. on opposite sides of the center line of the joint tie. The Baltimore & Ohio Ry. has suspended joints, with shoulder ties 20 ins. c. to c. The splice bars are 30 ins. long, of similar section, weighing 28.88 lbs. each, and having oval holes ⅞ × 1⅛ ins. The bolts are 4¾ ins. long over all, ¾-in. diameter, with cup heads, and necks ¾ × 1⅛ ins.; the nuts are 1¼ ins. square and ¾-in. thick. The three-tie joints of the Chicago, Burlington & Quincy Ry. have shoulder ties 8 ins. wide and 8 ins. apart in the clear. The splice bars are 38 ins. long, with six 15-16-in. bolt holes, 5 ins. c. to c. The bars are clear of the ties (C, Fig. 37) and weigh 63.75 lbs. per pair. The six bolts, nuts and nutlocks weigh 8.26 lbs.; making the total weight of splice about 72 lbs. The spike slots are ¾-in. wide and ⅝-in. deep, and are 3⅞ ins. from one end and 1⅞ ins. from the other end of the bar. The bolts are ⅞-in. diameter, 4 ins. long under the head, the head being 1 7-16-in. square and 13-16-in. thick. The nut is square, ⅞-in. thick, and the nutlock 1 3-16-in. diameter and ¼-in. thick.

Expansion Joints.—With continuous rails expansion joints must be placed at intervals to allow for creeping, and these are made with switch points. A similar arrangement is also used in tracklaying to close up between

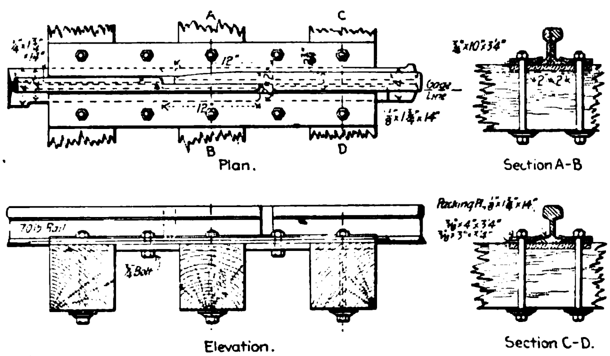


Fig. 43.—Expansion Rail Joint; Poughkeepsie Bridge.

new and old work. On long iron bridges and viaducts, some special joint must be used to allow for the expansion and contraction of the structure, and Fig. 43 shows the form used on the Poughkeepsie bridge, which provides for several inches of movement. A heavy base plate and upper packing plates form a trough in which the rail ends slide, the rails being "halved" for a length of 12 ins. Neither rail has its web cut. On the gage side of the rail the line is made perfect by planing off from the inside of the head an amount equal to the thickness of the web, the rail being slightly bent beyond the joint so as to permit this. The other rail is left of its original thickness. From the outside of one rail and the inside of the other ½-in. of metal is planed off, so as to make the rails enter truly at the joint, although their webs are 15-16-in. out of line. The axis of the joint is therefore ¼-in. in from the axis of the rails on each side of the

joint. The full width of rail head is 2 13-16 ins. The thin end of the left rail is 15-16-in. wide. All the sharp ends are rounded, but instead of the long outside taper of the right rail, it would have been better to bend down the top, leaving the full width. A double-flanged worn wheel would not then crowd the wheel over and cause derailment, which is likely to occur with any kind of horizontal bevel such as shown in the figure. The rounding on the gage side, however, is highly desirable.

Track Material.

The quantity of material on one mile of single track, with 30-ft. rails (giving 352 joints) is given in Table No. 9, and it may be noted that the weight of rail per yard divided by 7 and multiplied by 11 gives the weight in gross tons (2,240 lbs.) per mile of single track (two rails):

TABLE NO. 9.—QUANTITIES OF TRACK MATERIAL.

	No.		No.
Rails, 30-ft. long	352	Track bolts (6-bolt joints)	2,112
Ties, 16 per rail	2,816	Nuts (4-bolt joints)	1,408
Tie plates (2 on each tie)	5,632	(6-bolt joints)	2,112
Splice bars	704	Nut locks (single) (4-bolt joints)	1,408
Joint bridge plates	352	(6-bolt joints)	2,112
Track bolts (4-bolt joints)	1,408	Spikes or screws, 4 per tie	11,264
Clips for screw spikes, 4 per tie	11,264		

CHAPTER 7.—SWITCHES, FROGS AND SWITCHSTANDS.

Switches.

The switch is the device by which a train is diverted from one track to another, and the oldest form of switch was a loose pivoted tongue moving horizontally to give a clear flangeway for one or other of the diverging tracks, but the split switch was introduced in England as early as 1825. In this country, however, the stub switch was generally used on the earlier railways, and became the almost universal pattern, and it is only within recent years that the split switch has come into general use.

Stub Switches.—The stub switch, which is still in use more than it ought to be, consists of two movable rails connected by transverse rods. These rails are fixed at the heel, or end farthest from the diverging tracks, and have the toes or free ends sliding so as to coincide with the ends of the stub or fixed rails of one or other track, as shown in Fig. 44. The throw or movement of the free ends is usually 4 or 5 ins. for standard gage tracks. The switch rails should be two 30-ft. rails spiked to the ties at the heel, the rest of the rail being free to slide on the slide plates on the ties. They may be spiked for a length of 5 ft. for a 7½° curve and 12 ft. for a 15° turnout curve. If not spiked at all, but only hinged by the splice joint at the heel, the rails will not be curved when thrown for the turnout, but will remain straight, forming an angle or kink at the toe and heel. When spiked, however, for a length according to the frog number, the rails will, when thrown, be sprung to approximate to the proper curve. On the free length the rails are connected by four or five switch rods or tie bars, flat or 1½ to 1⅝ ins. diameter, and for main track there are sometimes two rods at the toe. The ends of these rods have welded pieces with jaws embracing the rail base, and the rods at the toe should fit tightly, so as to prevent any independent motion of the two rails, and to retain the

exact gage at the toe. Mr. Parsons, in "Track," says that these rods, weighing about 35 lbs. each, can be made by one forge, at the rate of one connecting rod and four switch rods per day. The toe of each rail rests on a head plate or head chair, Fig. 45, about 10×16 ins., which has a lug on the outer side to limit the throw, and is also formed to hold the ends of the stub rails in position and keep them from creeping. These chairs may be of cast iron, wrought iron or steel. The latter is preferable, as less likely to fracture under the shocks it has to sustain, and the base plate should be about ¾-in. or 1-in. thick, with riveted stops and slotted clamps of 1¼-in. metal holding the base and web of the stub rails to prevent creeping. The ends of these rails should be bolted together, with spacing fillers between, and sometimes have a ¼-in. iron strap across the ends and bolted

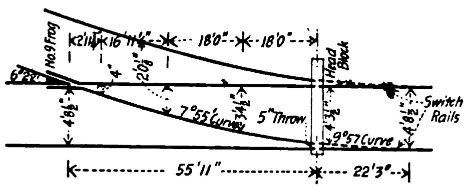


Fig. 44.—Stub Switch.

through the webs. The head chairs are spiked to a heavy timber called the headblock, which is about 12 ins. wide, 8 ins. thick and 12 to 16 ft. long. The end which projects beyond the ties carries the switchstand, consisting essentially of a lever and crank with a connecting rod to the head rod or bridle rod at the toe of the switch rails. The spikes which fasten the head chair may also hold the stub rails. With straight main track, the switch rails are straight when set for that track, and are sprung to a curve when thrown or set for the turnout or sidetrack.

This form of switch is neither a safe nor an economical one, even when fitted with such devices as the safety castings of the Tyler or Cooke

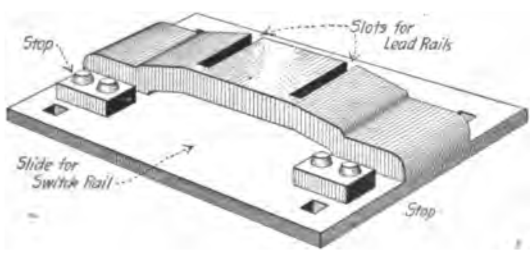


Fig. 45.—Head Chair for Stub Switch.

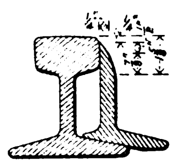


Fig. 46, A.
Form of End of Switch Point; Norfolk & Western Ry.

switches, which move with the switch rails and carry wheels coming along the wrong track, instead of letting them drop off the ends of the stub rails onto the ties. A train trailing through a misplaced ordinary stub switch must inevitably be derailed, and if the throw is not exact, so that the ends of the switch rails do not coincide closely in alinement with the ends of the stub rails, a sharp flanged wheel is very likely to cause a derailment. The loosening of head-chair spikes, wear of rail ends, and wear of connecting rods and other parts, are likely to cause lost motion, and make the throw

irregular, while under heavy traffic it is difficult to keep these switches in proper condition. In yards having stub switches a very large proportion of the track work is for maintaining, fitting and repairing the switches, and repairing the breakages and distortion of switch rods, due to derailments. Another serious objection is the wide space between the ends of the stub and switch rails, which frequently amounts to or even exceeds 2 ins., causing a destructive pounding of wheels and rail ends. On the other hand, in very hot weather the switch rails may expand so much as to be jammed in the head chair. This may be avoided to some extent by beveling the rail ends for about 12 ins., so that they lap side by side, as in the rail connections at drawbridges. This is done in the Elliot lap switch. A large proportion of the switch derailment accidents have been due to misplaced and defective stub switches, and it is satisfactory to find that it is rapidly being superseded by the split switch, especially in main tracks. The latter is very much safer, gives an unbroken rail in each position, and is much easier riding, while it is less severe on the car wheels and requires less labor for maintenance.

Split Switch.—The split switch consists of two point or switch rails, (either straight or curved to fit the curve of the turnout), planed down, tapering to a vertical edge, so that the ends will fit close against the main or stock rails. The heels of these rails are towards the diverging tracks, which

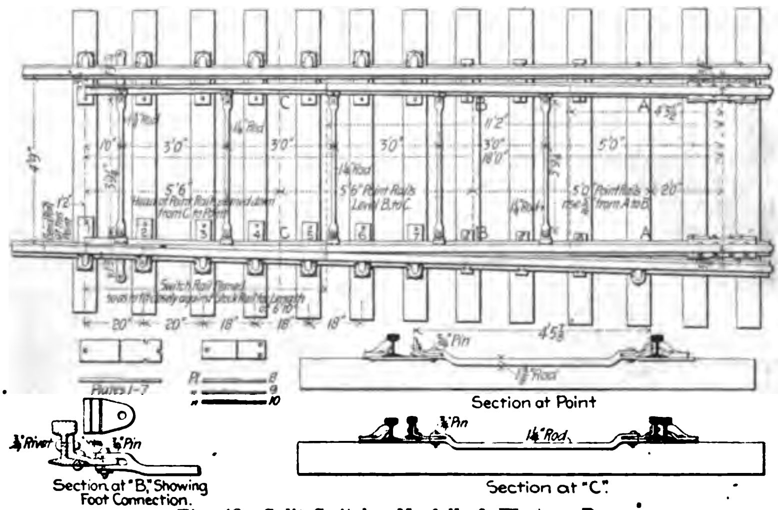


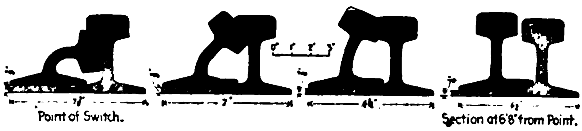
Fig. 46.—Split Switch; Norfolk & Western Ry.

is the reverse position of the stub switch rails. The two outer rails of these tracks are continuous, that is to say that the outer rail of the main track continues unbroken, while the inner rail follows the curve of the turnout. The switch rails are between these stock rails and the throw is from 3½ to 5½ ins., so that when one switch rail is home against the stock rail, the other is 3½ to 5½ ins. clear from its stock rail at the point, as shown in Fig. 46. The distance between gage lines is also about the same at the heel, the clearance between the rail heads being 2½ to 3½ ins., preferably 3 ins. The switch rails are connected by transverse switch rods or tie rods

(generally flat bars with jaws on the ends, but sometimes round rods passing through the rail webs), and are operated in the same way as the stub switch, the rails sliding on iron or steel plates or chairs spiked to the ties. These plates should extend under the stock rails, acting as tie-plates to prevent cutting of the tie and consequent tilting of the rail, which would widen the gage. These slide plates may have the slide seat pressed up above the level of the plate, and a lug pressed up to hold the heel of a rail brace on the outside. In the switch of the Norfolk & Western Ry., shown in detail in Fig. 46, there are 20 wrought iron slide plates; plates 1 to 7 are 18⅜ × 5 ins., ½-in. thick for 9⅝ ins. and 13-16-in. for 8¾ ins.; the other three are 14⅜ × 4 ins., with the raised part 7¾ ins. long, and the thickness is as follows: No. 8, ⅜ and 11-16-in.; No. 9, ⅜ and 19-32-in.; No. 10, ⅜ and ½-in. All have ¾-in. spike holes. Instead of two slide plates on the first tie at the switch, a single plate should be used, extending nearly the full length of the tie and having shoulders or lugs to fit the outside flanges of the stock rails and lugs to fit the heels of the rail braces. The end switch rod or head rod should be adjustable, so that wear or slack can be taken up to keep the gage true. In the ordinary form of the Weir switch (Weir Frog Co., Cincinnati, O.), the adjustment is made by a turnbuckle, each end of which has a right-hand thread, so that the gage is not affected by turning the turnbuckle (as by persons tampering with the switch), but the rod must first be disconnected, and the bolts removed from the head rod fastenings. The switch connecting rods may be grouped together near the toe of the switch, or in some cases the head rod alone is used, and this is very common in English practice. The rods should lie between ties spaced about 4 ins. apart to protect them from injury in case of derailment.

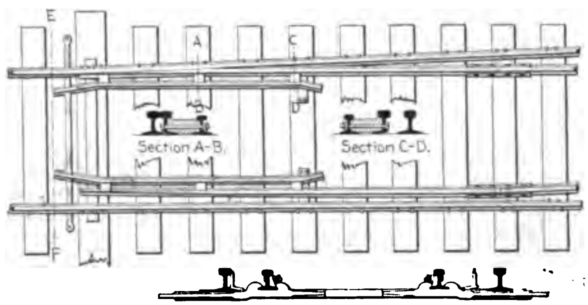
The length of switch rail is usually 15 or 18 ft., but 19, 20, 21, 22, 24 and even 30 ft. are used (the latter on the Pennsylvania Ry. for connections with third and fourth tracks). An 18 or 20-ft. switch rail makes an easy riding switch under fast traffic. If a 30-ft. rail is cut in two pieces, 15 ft. 1 in., and 14 ft. 11 ins. long, planed to shape and placed in the curved and straight track respectively, the heels will be exactly opposite, so that the joint ties at the heel will be square across the track. Switch rails 10 ft. long are often used in yard work. For switches leading from the outside of curves on main line, the switch rail on the inner side of the main track curve should be about 24 ins. longer than the other, with a guard rail opposite to guide the wheels in the reversal of the centrifugal motion of the train and prevent undue wear of the switch rail. The end of the switch rail is left about ⅛-in. thick, and the top of the rail is planed down on a slope for about 15 ins. at the end, giving a drop of about ¾ or ⅞-in. below the top of the main rail, the corner of the switch rail being rounded off vertically. This is to prevent wheel flanges from striking the point of the switch rail. The point of the Norfolk & Western Ry. rail is shown in Fig. 46A. At 12 or 15 ins. from the toe, the heads of the two rails are level, but then the switch rail rises to ¼ or 5-16-in. above the main rail in a length of about 3 ft. 6 ins. Back from this the head of the switch rail slopes down to the heel, where it coincides with the level of the main rail. The object of this is to carry worn or hollow tires and prevent them from cutting the main rail. In the form of switch rail usually employed the head and base are planed away on the inner side to allow the point to fit against the head of the main rail (or in some cases even under the head of that rail at the extreme point), the base of the switch

rail sliding up on that of the main rail. As the switch rail is not parallel with the main rail, it is necessary, in order to obtain the feather edge at the point, to plane off a portion of the head and a portion of the web on the other side, so that the thin end of the switch rail is weakened and its stiffness reduced. This part of the rail may be stiffened by a T-iron riveted along the outer side of its web, while in the Stewart switch (Morden Frog & Crossing Works, Chicago), Fig. 47, this cutting and weakening of the switch rail is avoided by twisting the rail on its web, so that



47.—Stewart Switch.

at the point end the outside edge of the head will be on top, the web being there bent at right angles, while the degree of twist diminishes towards the heel, the rail reaching its normal position at 6 ft. 8 ins. from the point, as shown. At the point the switch rail is raised by a slide plate to allow its base to overlap that of the main rail, and also to allow the head to rest against the web of the main rail. By planing away a very small portion of the head of the switch rail it is allowed to fit closely to that of the main rail, and but little of the metal of the main rail is planed away, as shown by the dotted lines. In the Channel split switch (Pettibone, Mulliken & Co., Chicago), Fig. 48, a guard rail about 9 ft. long is bolted to the inside of each switch rail, with the proper flangeway, the flaring ends extending beyond the switch rails and having the switch rod connected to them. No tie-bars are used. Each guard rail is held by three bolts and spacing blocks.



Section E-F.

Fig. 48.—Channel Switch.

Rail braces are generally placed outside the stock rail, on at least two ties at the toe of the switch, and sometimes back as far as the switch rail bears against the main rail. Stop lugs are also sometimes bolted to the web of the switch rails, about 7 ft. and 10 ft. 6 ins. back from the point, which bear against the web of the stock rail when the switch is thrown. Guard rails are sometimes placed close in front of facing switches in order

to steady all car wheels in proper line for taking the switch, thus preventing the toes from being struck and preventing sharp flanges from taking the wrong side of a loose switch rail not set well home. These guard rails are either parallel with the track rail, or slightly flared to give the narrowest width of flangeway just in front of the switch rail. The Pennsylvania Lines use two straight 6-ft. guard rails, while the Boston & Albany Ry. has a single 10-ft. guard rail on the side opposite the turnout, this rail being set with its end 6 ins. from the switch point and giving a flangeway of 3 ins. at the heel and 1¾ ins. at the toe, the throw of switch being 4½ ins. These guard rails are not generally required for well built switches having a throw of 4 ins. or over, except for switches on sharp curves. It is, however, a good plan to put in a tie rod or bridle rod just in front of the switch, to prevent any widening of gage of the stock rails, and also to use a long slide plate on the first tie, extending right across the track, as already noted.

Automatic Switches.—In the safety or "automatic" switch, of which the Lorenz switch is a familiar example, the connecting rod from the switchstand is fastened to a strap surrounding a stiff spiral spring carried by the head rod, as shown in Fig. 49. The connecting rod passes through

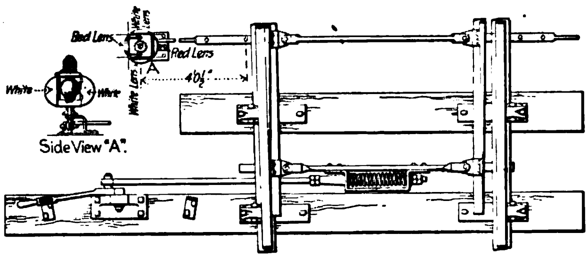


Fig. 49.—Lorenz Switch.

the spring, and the adjustment of length to make the switch rails fit properly against the main rails is effected by a nut on the rod at each end of the spring. This spring is stiff enough to make the connecting rod and head rod act as though rigidly connected when the switch is operated from the switchstand, in the usual way, but if set for one track and a train trails upon it from the other track, the pressure of the wheel flanges will force the switch rails over by compressing the spring, so that the train is not derailed and the switch connections are not broken. The spring returns the switch to the position as set from the switchstand, so that if a train in making switching movements trails partly through a closed switch and then backs up again, the train will be "split," the cars beyond the switch keeping their track, while those which have passed through the switch will take the track for which the switch is set. This would probably result in derailment, with damage to cars and switch. To provide against this, the switch is sometimes so arranged as to remain in the position to which it is thrown by the wheels, but this is a dangerous plan. The objection to the former arrangement, above noted, is not of great importance, as switches are not intended to be trailed through when closed (especially main track switches), as a general thing, and such an accident as splitting a train in this way would indicate neglect

and carelessness on the part of the train crew and switchmen. In some cases a lock is fitted to lock the switch when set for the main track, so that it cannot be trailed through from the side track without breaking the connections, but can be safely trailed through for the main track when set for the side track. A somewhat serious objection to the automatic switch is that if ice, stones or other obstructions get between the switch and main rails, the switchstand or lever can be thrown, but will merely compress the spring connection without throwing the rails full home. This may be partly obviated by the use of an automatic switchstand, described later, by which the lever cannot be fully thrown unless the switch is also fully thrown, and the automatic switchstand is the more generally used. As most roads have orders against trailing through closed switches it would be better to use rigid switches and rigid switchstands, which is now the practice on some roads.

Single Point Switch.—This has a movable switch rail (like that of a split switch) on one side, and a fixed point rail and guard rail on the other side, but it is decidedly inferior to the ordinary form of split switch, and is now only occasionally used. Probably the best known of this pattern is the Tracy switch, having a long guard rail opposite the moving rail, the flangeway opening out towards the heel to admit the blunt point of the fixed rail which forms the end of one main track rail. This fixed point is opposite the heel of the moving rail and lies between the guard rail and the continuous rail of the main track and turnout.

Wharton Switch.—This gives an unbroken main track, when set for this track; while when set for the side track it carries the wheel flanges over the head of the main rail by means of an inclined elevating rail and inclined grooved rails, operated like the switch rails of a split switch, as shown in Fig. 50. When set for the turnout, the grooved switch rail A (8 or 9 ft.

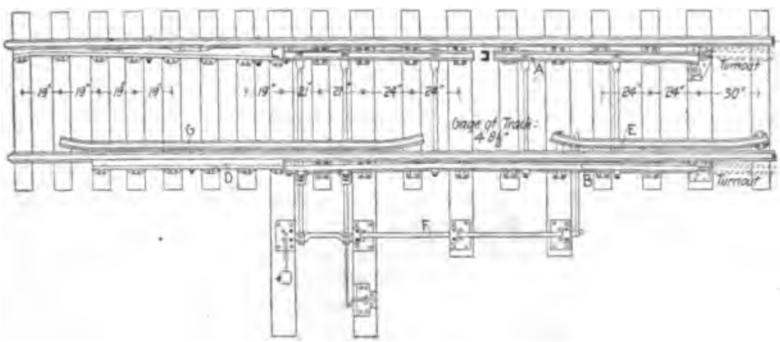


Fig. 50.—Wharton Switch.

long) raises the outer wheels 1½ ins. above the main rail, its heel bringing them upon the raised lead rail of the turnout. At the same time the elevating rail B, on the outside of the main track, engages the outside of the treads of the inner wheels. If trailed through from the side track when set for the main track (as in Fig. 50) the wheels run upon grooved safety castings C, D, the latter of which guides the inner wheels over the main rail, when the flanges drop into place. If trailed through on the main track

when set for the side track, the wheels throw the switch by forcing back the pivoted guard rail E, which rests against the main rail when the switch is set for the side track, and is connected with the operating shaft, F, of the switch. The inside guard rail, G, should be not more than 2 ins. from the main rail, so as to force the wheels to mount the elevating rail, B, and keep them in position until the flanges have cleared the main rail. The elevating rail should also be set close to the main rail. A modified form is now made in which all parts are made from ordinary rails, the grooved rails being dispensed with. Owing to the sharp elevation of the switch rails, this device is not adapted for switches used at high speeds, and though at one time quite extensively used, it is giving place to the ordinary split switch. It is best adapted for lay-over sidings, etc., not used more than a few times a day, and at speeds of not over 20 miles per hour. (Wharton Railway Switch Co., Philadelphia.)

Duggan Switch.—So many devices and modifications in railway switches have been patented and introduced that it seems as though nothing very novel could be devised, but the Duggan switch has the decided novelty of switch rails moving vertically instead of horizontally. In Fig. 51, the

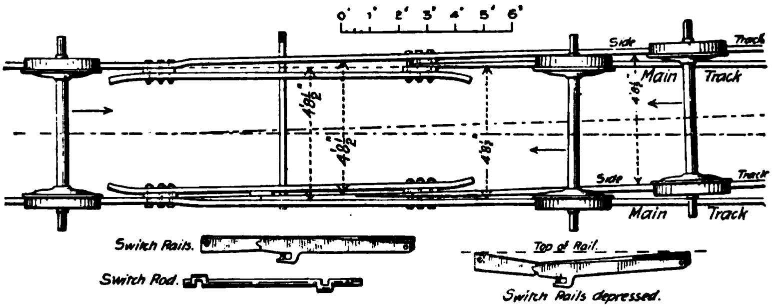


Fig. 51.—Duggan Switch.

lower set of switch rails is shown in place, so that a train would be turned onto the side track. If these are depressed, and those on the opposite side of the track (shown by dotted lines) are raised, the train will take the main track. The rails when raised are slightly below the level of the head of the track rail. The switch rails are of cast steel, hinged at the outer ends and having a knuckle joint at the inner ends. They are operated by a shaft having two cranks, so that as one pair of switch rails is raised the other pair is lowered. The switch gives a continuous track for both main line and turnout, and can be safely trailed through in either position. It is found that its operation is not interfered with by snow. This switch (made by the Burnham & Duggan Co., of Boston) is in use on the New York Central Ry.

Facing and Trailing Switches.—Any switch is a facing switch to trains running towards the toe of the switch, while it is a trailing switch to trains running toward the heel of the switch. In order to reduce the danger incident to facing switches, especially with high-speed traffic, some few roads make as many as possible of their main line switches trailing switches, but this, of course, can only be done on double track roads. The Boston & Albany Ry. has about 90% of its main track

switches on double track arranged as trailing switches. In such cases, a train taking the side track must trail through the switch and then back through it as a facing switch. Where there is a down grade, however, which would require a heavy train to be started from rest and backed up grade through the switch, it is not advisable to do this.

Three-Throw Switches.—In some cases two turnouts diverge from the main track at the same point, necessitating the use of a three-throw switch. Where possible, it is best to set one in advance of the other, thus

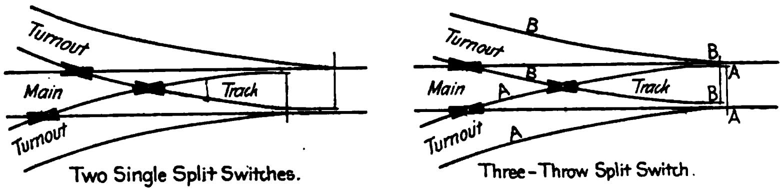


Fig. 52.—Three-Throw Switches.

keeping the switch rails distinct, though this latter arrangement will also throw the crotch frog off from the center line of the main track. Both plans are shown in Fig. 52.

Slip Switches.—Slip, puzzle or diamond switches are put in at the intersections of diagonal tracks, where there is no room for an ordinary switch and turnout. The curves are necessarily very sharp, but these switches

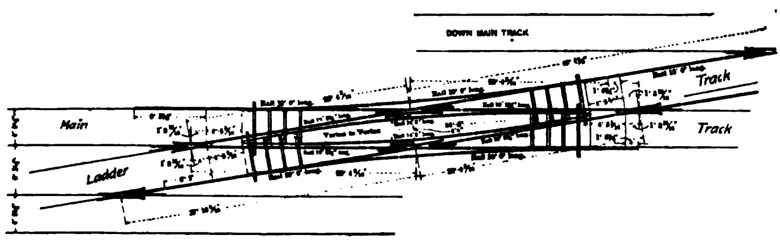


Fig. 53.—Slip Switches.

work very effectively in practice, and are largely used in yard work for connecting a lead or ladder track with the various parallel tracks which it crosses. A double slip switch is shown in Fig. 53. Such switches are not often used for main track connections, but at the Germantown Junction (Philadelphia) of the Philadelphia & Reading Ry., where the four-track line diverges to form two double track lines, there are slips 112 ft. long, having No. 15 frogs and 28-ft. switch rails, so as to give easy and safe passage for trains running at high speed.

Switch Protection.—The unprotected switch is one of the greatest dangers to traffic. Periodically a trainman leaves the switch open after his train has entered the side track, thus permitting the following train to run on the side track and collide with the first train; while with equal frequency a careless or weary man sets a switch, and then startled by an approaching train forgets that it is set and hurriedly changes it, thus perhaps turning an express train onto an occupied side track. Such accidents may be prevented by the use of a distant switchstand, described later, or by a detector bar at some distance from the switch, which is connected with the switch and cannot be moved while a train is passing, so that the switch

cannot be operated. A detector bar at the switch will also prevent the switch from being thrown while a train is passing over it. This bar is placed against the outer side of the rail head. It is somewhat longer than the greatest distance between wheels, and is hinged to vertical studs, causing it to move in a slight vertical arc parallel with the rail, which it cannot do while the wheels are over it. The bars should always be fitted to switches in busy passenger yards. To prevent a train or car on the side track from running onto the main track when the switch is set for the latter, a derailing switch with stub or split rail is placed on the outer rail of the side track and interlocked with the switch, being open (to act as a derail) when the switch is set for the main track. It is better, however, to have the side track continued to a stub end beyond the switch, the switch being normally set for the stub. This prevents derailment, while ensuring equal safety, and the stub track may have its rails covered with sand to check the speed of the cars. A derailing scotch block or fixed scotch block is sometimes used in similar cases, generally on side tracks where cars are left standing, the purpose being to prevent the cars from being accidentally or maliciously moved so as to foul the main tracks. The two switches of a crossover road, connecting two parallel tracks, are sometimes connected so as to be operated simultaneously. Distant signals and interlocking plants should be used at main line switches and yard entrances, as noted under "Switchstands."

There are various designs of switches to be operated by the engineman while the train is running, but they are based on the entirely wrong idea of letting the engineman interfere in regulating the train service, and such plans would be pretty sure to result in disaster. There is, however, no fear of any such system coming into more than the most limited practice.

All main line switches should be provided with safety devices, signals, etc., and should be interlocked with signals at junctions or other busy points.

The switch angle is that included by the two positions of the moving rail of a stub switch, and by the stock rail and switch rail of a split switch. A switch is right or left handed according as the turnout is to the right or left of a man standing on the main track and looking towards the turnout.

Frogs.

Cast-iron frogs, for rails on stone blocks, were used in England in 1825; and on the Portage Ry., in Pennsylvania, in 1835, these latter having pockets for the ends of the English edge rails. Cast iron, however, is a poor material for this purpose, and has been abandoned, and though cast steel has been used to a limited extent, frogs are now almost universally made of steel rails planed to shape, as shown in the diagram, Fig. 54, the dotted lines indicating the rail connections. The two middle rails of the tongue are planed to fit together, one of them forming the point and having the other dovetailed into it. The shorter rail should not be planed to a sharp point and fitted against the longer rail, but the latter should be notched about ¾-in., as shown, to receive the blunt end of the shorter rail. Usually the short point rail is placed upon the turnout and the long point on the main track, but in the Elliot frog these positions are reversed, it being claimed that this is the stronger arrangement, and the one which will best withstand the destructive effects of hollow worn tires.

The back of the frog, at the end of the tongue rails, is called the heel. The space between the tongue and the wing rails is the flangeway, or flange space, and in it is the flange filling, which is composed of spacing pieces fitting against the webs of the rails. Beyond the point of the frog the space between the wing rails contracts to a width equal to the flangeway (this narrow part being called the throat), and then widens out again to the toe (or mouth) of the frog. A sharp point to the tongue would soon be broken off, and the point is therefore made with a blunt end about ⅜ to ½-in. wide, and a few inches shorter than the true or theoretical point. It is sometimes strengthened by a piece welded against the web between the head and base of the rail, before the rails are planed, and the base of the tongue rail should be left full width at the end, the base of each wing rail being cut away as required to bring the rails close together. A raising block should be put at the heel, having an inclined surface to raise the inner flange of a hollow worn tire and prevent it from exerting a bursting effect by wedging in the narrow space at the heel. Such tires are most destructive to frogs, as noted later. The flangeways should be 1¾ or 1⅞ ins. wide, and never more than 2 ins., except for crossing frogs. The wings should be straight and true. At

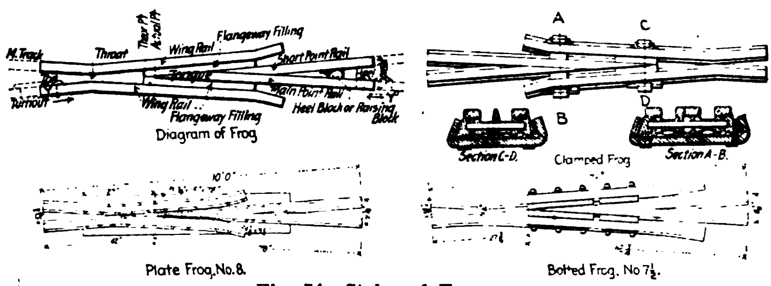


Fig. 54.—Styles of Frogs.

the heel of the frog the rails running from the switch are bolted to the tongue rails by ordinary splice joints, while at the toe of the frog the rails (lead rails) running to the switch are bolted to the wing rails. It will be seen by the diagram in Fig. 54 that the tread of the wheel X, moving to the left on the main track, will engage with the upper wing rail and be carried onto the main track lead rail bolted to the wing rail. The wheel Y, running to the right on the turnout, will be caught by the tongue of the frog, and be carried to the turnout rail bolted to the heel of the frog.

In a paper on "The Relation of Wheels to Frog Points and Guard Rails,"* Mr. A. A. Schenck pointed out that in examining to what extent the narrow flangeway is more desirable than the wide flangeway, mere width of tread bearing is not the only consideration, another important one being that simultaneous bearing on both frog point and wing rail is rarely secured, as usually either the point or wing rail alone carries all the weight. When both point and wheel are new, the bevel on the outer edge of the tread throws all the bearing on the frog point. A wing rail has

*Transactions of the American Society of Civil Engineers, May, 1894.

the same effect when it is badly worn by false-flanged wheels, is bent vertically (with one part low and another part "cocked up"), or yields under the load of the wheel. In such cases the width of flangeway is not of much importance. On the other hand many frog points "duck" as the wheel approaches, leaving the wing rail to carry all the weight, and this is aided by the narrow base which the rail forming the frog point usually has. In such cases the width of tread bearing is important, to carry the wheel firmly until the depressed portion of the frog point has been passed. Hollow tires also prevent simultaneous bearing. It is therefore desirable to ignore the frog point as a bearing, for some distance, and to use a narrow flangeway and a small limit in wheel gage. The destruction of a frog is due mainly to the shocks it receives, making the frog too loose and shaky for use, and increasing the wear on such a loose frog. Therefore, the narrow flangeway will not effect a very great increase in the life of the frog unless it is well cared for in other respects. The shock is generally assumed to be the blow upon the point, but it is probable that the lateral blow on the inside of the wing rail by the false flange of a trailing wheel, and also in the angle where the point rails come together (unless a raising block is used) strains the frog by a wedging action and loosens it more than a blow upon the point. The severe strain due to the false flange climbing to the height of the rail head will occur equally whether the flangeway is 1¾ or 2 ins. wide.

The number of a frog indicates the spread of the angle included by the tongue rails, the flare of these rails in a No. 8 frog being 1 in. in 8 ins. The number may be calculated (1) by measuring the distance between points where the width over gage lines of the tongue is 2 ins. and 3 ins. (which will be the frog number); or, (2) by dividing the length on center line from heel to true point by the width of or spread of heel over gage lines; or, (3) by taking the length from toe to heel and dividing this by the sum of the width over rail heads at the heel and between rail heads at the toe. The frog angle is the angle included by the tongue rails. A right-hand frog is for a turnout to the right, looking from the switch. A crotch frog is placed at the intersection of the lead rails of a double turnout, and its number is equal to that of the main frog multiplied by 0.707. The angles of the principal frog numbers are given in Table No. 10:

TABLE NO. 10.—FROG NUMBERS AND ANGLES.

	Degrees.	Minutes.		Degrees.	Minutes.
No. 5	11	25	No. 10	5	44
No. 6	9	32	No. 11	5	12
No. 7	8	10	No. 12	4	46
No. 8	7	09	No. 15	4	24
No. 9	6	22			

The frogs should be carefully laid and bedded level on the ties, with plenty of good ballast underneath, as they are subjected to very severe shocks. They should not be spiked to a gage ⅛ to ½-in. slack, or wide, as is sometimes done; unless they are on a curve where the gage is correspondingly widened. In other words, the gage at the frog should be exactly the same as that of the track.

There are various styles and makes of frogs. Bolted frogs, Fig. 54, have the parts held together by horizontal through bolts, ⅞-in. to 1-in. diameter; iron or steel fillers being placed between the webs of the rails.

They are light, but the bolts are liable to work loose unless riveted over, keyed, or otherwise secured, and the supposed advantage of being able to replace wornout parts without removing the frog is not often called into practice. Yoked, clamped or keyed frogs, Fig. 54, have yokes which pass under the rails and have their ends opposite the rail webs, iron or steel keys being driven between the clamps and the outer rails, while fillers are placed between the tongue and wing rails. One of the clamps should be opposite the frog point. The clamps are usually flat bars with the ends bent up to hold the keys, but in the Strom clamped frog (Pettibone, Mulliken & Co., Chicago), they are 1½ ins. wide and 3 ins. deep, set on edge, with the ends formed to fit the web, base and lower side of head of rail. These clamps are very stiff. They are held in place by two rods, with hooked ends engaging the ends of the wing rails, each rod passing through both clamps and being secured by spring cotters through the rod. Plate or riveted frogs, Fig. 54, have the rails riveted by their bases to a heavy iron or steel plate, or else to separate plates with spaces between to

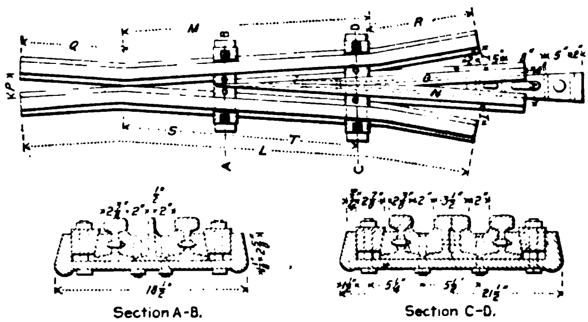


Fig. 55.—Rigid Clamped Frog; Pennsylvania Lines.

allow the rails to rest on the ties, and also to facilitate tamping. If one plate is used, resting on the ties, the lower rivet heads must be countersunk. An objection to plate frogs is that the rivets are liable to work loose and make a noisy clattering frog. Base plates are sometimes riveted to other styles of frogs. In filled frogs, the filling pieces should be properly shaped to fit snugly against the rails, and should extend 8 ins. beyond the point and back to the flare of the wing rails.

The stiff plate frogs of the Norfolk & Western Ry. for its 85-lb. rails are all 15 ft. long, with a length of 8 ft. from the frog point to the heel and 7 ft. from the frog point to the toe. These dimensions apply for Nos. 6, 7, 8, 9, 10 and 12, but No. 15 has 9 ft. 6 ins. from point to heel and 5 ft. 6 ins. from point to toe. The plates are ¾-in. thick, 42 x 22 ins. for Nos. 6, 7 and 8; 42 x 20 ins. for No. 9, and 60 x 20 ins. for Nos. 10, 12 and 15. They have ¾-in. rivets, with the lower heads countersunk, and ¾-in. square spike holes, the ties being spaced 18 ins., c. to c.; the frog point is ½-in. wide, and the flangeways are 2 ins. wide. The standard rigid clamped frog of the Pennsylvania Lines West of Pittsburg is shown in Fig. 55, and

the dimensions of these frogs of different numbers are given fully in Table No. 11; the dimension I is uniformly 3½ ins., and R is uniformly 20 ins.:

TABLE NO. 11.—DIMENSIONS OF RIGID FROGS; PENNSYLVANIA LINES.

Frog No.	Length.		H.	L.		M.		N.		O.		P.	Q.		S.		T.	
	ft.	ins.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ins.	ft.	ins.	ft.	ins.	ft.	ins.
4	7	6	15	5	5	2	1	5	0	4	4	7	1	8	0	10	1	0
4½	7	6	$13\frac{5}{16}$	5	6½	2	3¾	5	0	4	3	$6\frac{3}{16}$	1	6¾	0	11¼	1	1½
5	8	0	12	6	2	2	6½	5	0	4	2	$6\frac{11}{16}$	1	11½	1	0½	1	3
5½	8	0	11	6	4	2	9½	5	0	4	1	$6\frac{1}{8}$	1	10½	1	1¾	1	4½
6	8	0	10	6	8	3	0	5	0	4	0	6	2	0	1	3	1	6
7	8	0	$8\frac{9}{16}$	6	11½	3	5½	5	0	3	10	$5\frac{1}{8}$	1	10	1	5½	1	9
8	8	0	7½	7	3	3	11	5	0	3	8	4½	1	8	1	7	2	1
9	9	0	$6\frac{11}{16}$	8	1	4	5	5	4	3	6½	$5\frac{1}{16}$	2	0	1	9½	2	4
10	10	0	6	8	10	4	10	5	11	3	4	$4\frac{7}{8}$	2	4	2	0	2	7

All the frogs thus far described are rigid or stiff frogs, and it will be seen that there is necessarily a severe jolt as each wheel crosses the flangeway, especially if the wheel and frog are worn.

Spring Rail Frogs.—In order to make a smooth-riding main track, the spring rail frog has been introduced, and is now commonly used. It gives an unbroken main rail, the main track wing rail being pivoted and held close against the side of the tongue by a spring, so that there is no gap or flangeway to cross. The flanges of wheels of trains on the turnout force the spring rail outward by striking it at the throat in facing, or wedging between it and the tongue in trailing, as shown by Fig. 56. In this cut, A and B are the lead rails, C the spring wing of the frog, and D

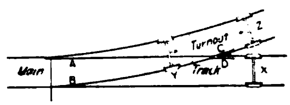


Fig. 56.—Spring Rail Frog.

the fixed wing. The wheels on the main track, X, have a continuous bearing, as the wing C is held against the frog point. The wheels on the turnout, Y, Z, force the wing C back by the wheel flanges entering between the wing rail and frog point.

In many of these frogs the spring is near the throat, but it is better to have it near the free end, while in some cases an additional spring is placed opposite the frog point. The outward movement is limited to about 2 ins. by rail braces or stops. To prevent the end of the spring rail from tilting up when the wheels pass the throat, there may be used either a "monkey tail" strap, bolted to the web and having its end passing under the frog rails, or a fixed bar bolted to the base plate, having its horizontal arm passing through a slot in the spring rail; or hinged holding-down arms working horizontally, may be used. The frog point and the sliding end of the spring rail should rest upon a base plate at least 3 ft. long, and the spring rail should fit close against the frog point for a sufficient length to give a full bearing to the wheels.

In the Illinois Central Ry. frog, Fig. 57, the top of the spring rail is planed down to allow the free passage of the false flange of a worn wheel, thus avoiding the opening of the spring rail by such tires. The limit of movement of the rail is 2 ins., which is the width of the throat and flangeway. A filler, 30 ins. long, is placed in the open flangeway, extending back from the frog point. The base plates are ½-in. thick. The Monarch spring rail frog (Carlisle Mfg. Co., Carlisle, Pa.), which is shown to some extent in detail in

Fig. 58, has the top of its spring rail ¼-in. to ⅜-in. lower than the top of the frog point, as shown by the section E, F, so that a false flange cannot strike the inner side of the rail and force it out, but passes over it and comes in contact with the outer side, thus hugging the spring rail tight to the frog. In frogs where no such provision is made the false flange of a worn driving wheel trailing from K may strike the spring rail near L, forcing it out and bending the stops M, so that the wheels drop onto the ties at the throat N. The point of the frog naturally wears out more than the spring rail, which tends to aggravate this danger. The clips O and the monkey tail P prevent the end of the spring rail from tilting up when

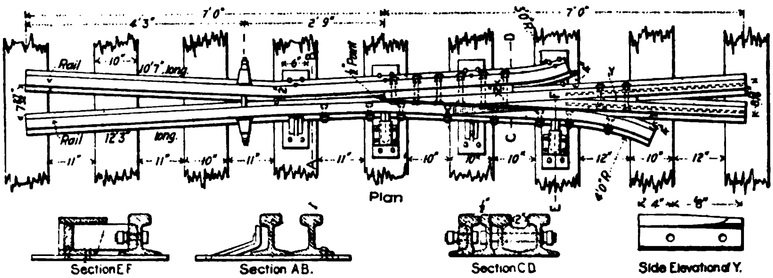


Fig. 57.—Spring Rail Frog, No. 10; Illinois Central Ry.

trucks are passing off the frog at R, and the spring rail bridle S prevents the creeping of the rails, and keeps the parts from binding or getting out of line. An additional spring is used, as shown by the section E, F; and filling or reinforcing plates are bolted along the spring rail and frog point. The parts are tied together by key bolts.

The spring rail frog is not required at junctions or in busy yards, where

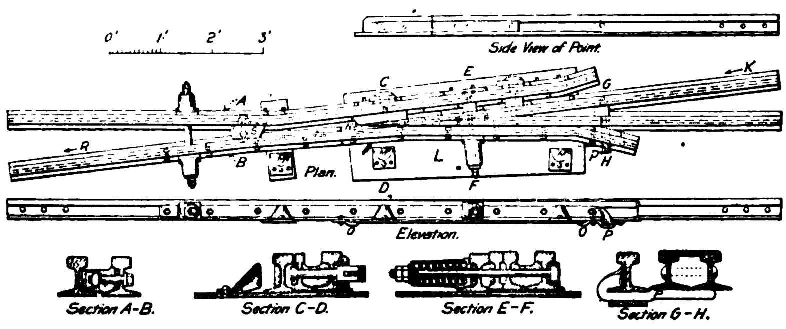


Fig. 58.—Monarch Frog.

one side is as much used as the other, but it is specially adapted for turnouts in main line service, under heavy and fast traffic, as it reduces the danger, makes a better riding track, and diminishes the wear and maintenance (the frog keeping in surface better than a rigid frog). It should not be used with rails lighter than 60 lbs. per yd. It is sometimes considered that the stiff frog, while less economical, is the safer in case of a broken wing rail, and that it offers a better resistance to hollow worn

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wheels. While this question of safety is a matter of varying opinion, it may be said that modern spring rail frogs are as safe as, if not safer than, rigid frogs, and the undoubted advantages of the spring rail frog cause it to be generally used,. and as now made there can be but little more danger in case of breakage than with a rigid frog. With a worn frog or a hollow tire there is some danger of the spring rail being forced out by a trailing main line wheel, the tread (with worn frog) or the false flange of a worn tire forcing it out and bending the stops so that the wheel will drop into the throat of the frog, but this may be prevented by beveling the top of the spring rail, or making that rail ¼ to ⅜-in. lower than the top of the frog tongue, as in the Monarch frog, so as to clear the wheels. Devices have been introduced by which the spring rail is locked against the tongue when the switch is set for the main track, and sometimes there is a short guard rail or re-enforcing rail outside the spring rail, so as to give

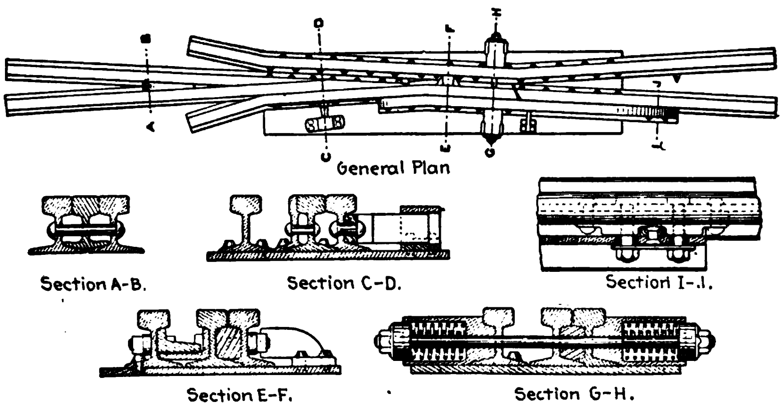


Fig. 58, A.—Eureka Frog.

extra security in case of the fracture of the spring rail. The Eureka frog (Elliot Frog & Switch Co., St. Louis, Mo.) has this outer rail bolted to the fixed and moving parts of the spring wing rail, these parts normally forming a continuous running rail with a miter joint opposite the throat of the frog, as shown in Fig. 58, A. The objections as to the clogging of the spring rail by snow and ice are found in practice to be of little moment, and spring rail frogs are largely used on roads which have plenty of snow and ice to deal with in the winter. In fact the spring rail frog is now practically the standard for main track frogs.

Vaughan Frog.—In this frog, Fig. 59 (and some others), the spring rail is pivoted at its outer end (or at the heel of the frog), and controlled by a spring placed nearly opposite the frog point. The filling block is so shaped as to guide the wheel flanges in case of any accident to the spring, and has a rib fitting under the head of the spring rail. In the ordinary spring rail frog, the greater part of the spring rail is used as the main track rail, but in the Vaughan frog only the end of this rail forms a part of the main track, and no derailment can occur if this rail is displaced, the wheels being carried across by the filling block, which is just low enough to clear the wheel flanges when the frog is in proper condition.

The Pennsylvania Ry. for some years abandoned the use of spring rail frogs, on account of the liability of the ordinary spring rail to be forced over by worn tires, as already described, but it has found the Vaughan frog very satisfactory in this respect.

Movable Point Frogs.—These are mainly used as crossing frogs, noted further on, but the Pennsylvania Ry. has used the Wood frog extensively in yards, where it is considered superior to ordinary frogs. There is no spring, but both wing rails move simultaneously, remaining in either position as set by the wheels. This is shown in Fig. 60.

Long frogs make a much better riding track than short frogs, and the

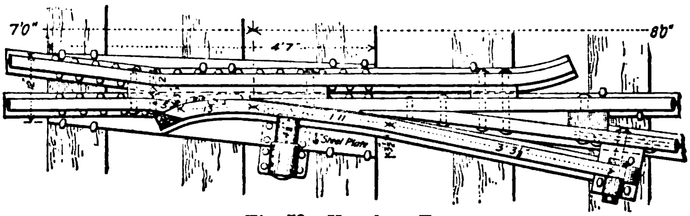


Fig. 59.—Vaughan Frog.

length should never be less than 6 ft. A good length is 10 ft., with 6 ft. from toe to point, and 4 ft. from heel to point, but 15 ft. is better for a spring rail frog, and rigid frogs are also made 12, 14 and 15 ft. long. For yard work, frogs may be 6, 8 and 10 ft. long. It is well to have one of the tongue rails longer than the other so that the splice joints at the heel will not interfere with each other. The wing rail for the curved lead rail may also be made a little longer than the other, for the reason that the curved lead B C (Fig. 56) is slightly longer than the straight lead A C. If the straight lead of No. 10 frog is 60 ft. (two lead rails, 30 ft. and 22

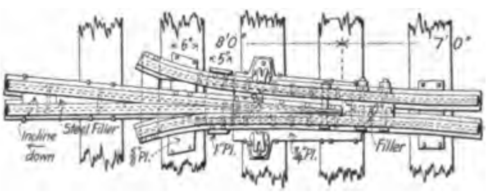


Fig. 60.—Wood's Frog; P. R. R.

ft.: toe of frog to frog point 8 ft.), then the curved lead will be nearly 2 ins. longer. This will bring the switch connecting rods 2 ins. out of square, which can be avoided by making the curved lead wing rail 2 ins. longer. If the wing rails are curved to fit the curve of lead, they will make an easier riding track, but this is a refinement rarely practiced.

It is desirable to have as few sizes of frogs as possible in regular service, and the tendency now is to have but two or three standard numbers, using special frogs where necessary. Some roads even specify a single standard for main track and yards, but it is doubtful if they adhere very closely to the standard, especially in yard work. The standard numbers of different roads are shown in the tables of standard track,* Nos. 7, 8, 9

* Appendix No. 1.

and 10, are those in most common use. No. 4 is sometimes used for sharp curves to warehouses, etc., but can only be used by switch engines with short wheelbase; the lead or turnout curve is 150 ft. radius. No. 6 is used in yards, especially for ladder track connections, so as to occupy as little length of track as possible. Nos. 7, 8 and 9 are better for yard use, and are sometimes used in main track. No. 10 is as sharp as should be allowed for main line turnouts, crossovers, etc., which are frequently used by road engines. Nos. 12 and 15 are used for crossovers and turnouts where trains run at high speed, No. 15 having a lead curve of 3°. When standards are adopted they should be introduced as rapidly as possible to replace the existing unsystematic arrangement of odd sizes and numbers of frogs, and if three numbers are made standard they should be such that the lesser numbers will fit as crotch frogs if double turnouts are necessary. Such turnouts, however, should not be used unless for special reasons. In laying out yards, shop tracks, and terminal connections, it is better to plot the layout to a large scale and then measure the leads, etc., from the drawing.

Frog Substitutes.—In view of the increasing speeds of trains and increasing number of turnouts, several attempts have been made to introduce devices to avoid the use of the ordinary frog and to provide an unbroken main rail, especially at main line turnouts where the main line traffic is much greater than that of the turnout. Such devices have not been used to any great extent. The Price frogless switch was introduced on the Allegheny Valley Ry. in 1885, by its inventor, Mr. C. B. Price, Division Superintendent of that road and a few are now in service. The lead rail of the outside of the turnout curve is gradually elevated so as to raise the wheels above the level of the main rail. When the switch is set for the turnout, a movable frog point is thrown so that its end rests on the main rail and carries the wheels over, while the movable end of the lead rail, forming the wing of the frog, lies against the main rail. This device can be trailed through in either position. The Ackerly frog, tried on the Chicago, Rock Island & Pacific Ry., has the lead rails brought together to form a flangeway like the throat of an ordinary frog and are then cut off square. The meeting rails are brought together like a frog point, but they end the full width of a rail, and these rails are hinged at joints 30 ft. back on the main rail, and 15 ft. on the turnout. This movable section is connected with the switch and moved like the switch rail of a stub switch, to correspond with one or other of the lead rails. Other devices have the frog point moving between the wing rails like the rail of a split switch. The MacPherson movable frog. worked in connection with the switch, has been tried with success on the Canadian Pacific Ry., its inventor being Mr. Duncan MacPherson, Division Engineer at Montreal. It has an unbroken main rail, a raised turnout lead rail, and a pivoted frog point resting on the main rail, as in the Price frog, but has only one moving part instead of three. Should a main line train trail through the frog when set for the turnout, the wheel flanges would mount the incline of the beveled heel of the frog, the wheel running along the frog and down another incline upon the main rail again, the guard rail opposite the frog holding the wheels over so that they cannot get on the wrong side of the main rail. The ends of these inclines are made to engage a wheel flange without causing a shock or blow. When the head of such a train reached the switch, each set of wheels

would open the switch, but this would not throw the frog, owing to the placing of a spring connection in the switch rod, as in the Lorenz switch. The frog cannot move unless the switch lever is unlocked and thrown. The old Dooley frog had a pivoted rail working in connection with the switch. Some of these devices are shown in Fig. 61.

Crossing Frogs.—Where two tracks intersect, crossing frogs must be

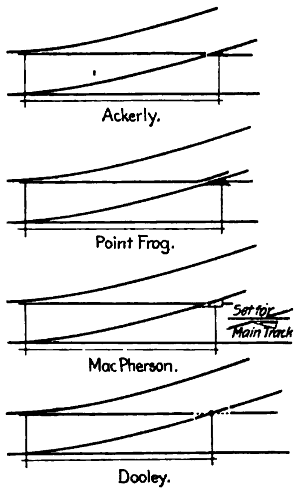


Fig. 61.—Frog Substitutes.

used to give a flangeway in both directions, and as there is very great diversity in the angles of crossings, the frogs and crossings have generally to be specially made for each case. They are usually of steel rails, cut to length, shaped and bolted together, with filling pieces between, and

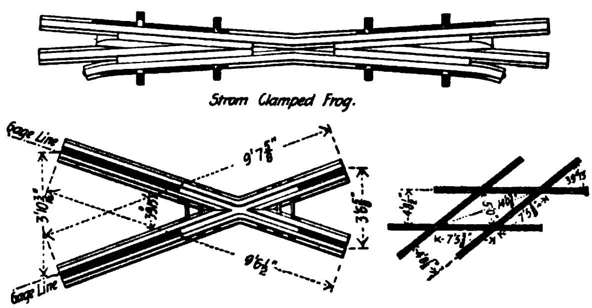


Fig. 62.—Crossing Frogs.

with a baseplate under each corner. The rail ends at the corners may be beveled off to a miter joint, or have one rail butted against the other, while the inner or guard rail may be continuous (as it usually is in crossings of 45 to 90°) or may be stopped and flared out like a wing rail at each corner. These plans are shown in Figs. 62 and 98. The crossing may be built

up without a joint between the frogs, but this makes a very heavy section for transportation and does not admit of repairs without taking up the crossing. As a rule it is better to have a joint in each side. The greater the angle of crossing the greater will be the wear on the frogs, as the wheels of each track cause considerable battering in crossing the flangeway of the other track. With an angle of less than 8°, or if one or both tracks are on a curve, two sets of short movable split switch or point rails may be used instead of crossing frogs, as shown in Fig. 63. The points are set toe to toe and operated simultaneously by a lever. The same arrangement may be applied at the crossing of slip switches. The creeping of the track sometimes makes it difficult to keep the crossings in line, unless means are taken to brace or anchor them. In the Norfolk & Western Ry. practice, as exemplified by a crossing of 98°, the entire crossing frog is in two pieces. Under each corner is a plate ¾ × 24 × 36 ins., to which the main rails and guard rails are secured by ¾-in. rivets, 4 ins. pitch, having the lower heads countersunk. There are strips outside the rails and a filler between the main and guard rails, all held together by three bolts in each leg of the crossing. These crossing frogs correspond very closely with the company's standard plate frog, with the addition of the strips and fillers.

In order to avoid the shock at the open flangeway, crossings have been made with elevating rails, having the flange filling inclined to carry the wheels of the less important track across the other track on their flanges. This is rarely done with steam railways, but is adapted for horse car lines crossing steam railways. For cable and electric railway crossings of steam railways, regular built-up crossings are usually preferred, giving a flangeway for both roads, and a third or "easer" rail being placed on the outside of the main rail. This reinforcing rail, with its head touching that of the main rail is also used on steam railway crossings to carry the false flanges of badly worn or grooved wheels and prevent the battering which such wheels cause on the rails at the gaps for the wheels on the other track. Devices have been invented to give a continuous rail for whichever track is signaled to have the right of way, but they are little used. In the Fontaine crossing, there are four movable corner pieces, each riveted to a horizontal rotating plate, the four plates being operated simultaneously by rods connected to a central vertical shaft which is interlocked with the signal lever.

In the renewal of crossings careful measurements should first be made of the angles, and of the gages of tracks, so as to avoid badly fitting work due to a confusion of the gages of 4 ft. 8½ ins. and 4 ft. 9 ins. It will very generally be found that the alinement of the crossings has been affected by creeping of the rails. In new crossings, with accurate alinement, the length of wing rails may usually be taken arbitrarily, without regard to other conditions, but in renewing old crossings, or in a crowded situation, it may be necessary to make the lengths to fit existing rail connections, more especially for crossings of foreign tracks. If the two tracks have rails of different weight, the crossing should be build of the heavier section, and if the difference is considerable, a length of the heavier rail should be laid beyond the frogs on the lighter track, so as to avoid excessive shock at the crossing. The lighter rails should have proper shims and chairs to bring them in proper surface with the frog rails. The angle of intersection should be measured with the transit, and in the

case of curved tracks this will be equal to the angle between the radii to the common point. If the alinement of track has become bad the proper location should be made before the frogs are ordered, and a determination arrived at as to whether the frog is to be made to fit the alinement or the alinement to fit the frog. Centers should then be given from which the trackmen work in putting in the crossing. The degree of curve should be verified by measuring the tangent offset, and by taking supplementary angles, checked by measuring with a chain or steel tape. Further particulars of this will be found in Part II., Chapter 18, "Gage, Grades and Curves."

Repairs to Frogs.—When a frog has become worn it makes a rough riding track and may be dangerous, so that prompt repair or renewal should be made. On roads where only slight repairs are made and all worn material goes to the scrap heap, there is much waste in throwing away worn frogs, as they are usually worn out in one part only. In order to effect a reduction in the expenses for new frogs and switch points, some roads have adopted a practice of having extensive repairs made by a good blacksmith. Thus when a worn frog is taken out, it is sent to the shop to have a new wing rail put in, the point shimmed up to its proper level, or new bolts, rivets or keys put in, making the frog practically as good as new. New wing rails are made from pieces of good rail from the scrap pile, the old rails taking their place as scrap. Switch points may also be repaired in the same way.

Guard Rails.

Opposite the frog, and on the inner side of each continuous rail, is placed a guard rail to hold the wheels in line and prevent them from striking the point or getting on the wrong side of the frog point. They are sometimes omitted in yards on account of the liability of switchmen and yardmen to stumble over them. These guard rails should be not less than 12 or 15 ft. long, straight for 6 or 8 ft. at the middle and having the ends flared out gradually so as to bring the wheels steadily into the flangeway. On some roads the guard rails are bent to a uniform curve, and placed with the narrowest part of the flangeway opposite the frog point. the idea being that the wheels should only be held over just at the frog point and released as soon as they have passed the frog, any attempt to hold them over longer than this resulting in extra wear of the frog or guard. The straight rails, however, are much to be preferred. A 15-ft. guard rail should have 8 or 9 ft. of its length ahead of and 7 or 6 ft. back of the frog point. These rails are spiked to the ties and supported by rail braces, with not less than two braces on tangents and four on curves. They may also be bolted to the web of the track rail, spacing blocks or fillers being used to insure the correct width of flangeway, or may be secured by clamps similar to those of clamp frogs. In one form, the inner end of the clamp holds the base of the guard rail, and wedges are driven between the main rail and the outer end of the clamp; the flangeway is maintained by a filling block which has a tongue passing down through a hole in the clamp and secured by a split key under the clamp. The easy riding of trains at turnouts, and the durability of the frogs, depend largely upon the proper placing of these guard rails. The gage of track should be the same at the frog as at adjacent parts, and should be accurately maintained, measuring from frog point to main rail. The standard guard rail gage is 4 ft. 5 ins. out to out of heads of wing and guard rails. The flangeway between guard and track rail should be uniformly 1¾ ins.,

though it is sometimes 1⅞ ins., or even as much as 2 ins. on lines where the gage of 4 ft. 9 ins. is still in use (this gage, however, is very objectionable). The standard guard rail gage adopted by the Master Car Builders' Association in 1894 has lugs 1¾ ins. wide and 4 ft. 5 ins. apart in the clear. The importance of accuracy and uniformity in width of flangeway is not sufficiently well understood by trackmen, and they not infrequently guess at the width or make it to suit their own individual ideas on the matter. The standard width should be insisted on and should be measured at the widest parts of the rail head (over the bottom of the heads of rails with flaring sides). The ends should be about 4 ins. from the track rail, this space being protected by a foot guard. The standard guard rail adopted by the New England Roadmasters' Association, in 1894, is 15 ft. long, straight for 7½ ft. at the middle and the ends curved to a clearance of 4 to 5 ins. At least five rail braces and two guard rail clamps should be used, and the base of the guard rail should be planed off to allow of spikes being driven between it and the track rail. The distance from the gage side of frog point to gage side of guard rail should be 4 ft. 6¾ ins., giving a flangeway of 1¾ ins. The Norfolk & Western Ry. uses an 18-ft. guard rail, straight for 10 ft., with a flangeway of 2⅛ ins., and an end clearance of 4 ins. It extends 9 ft. 10 ins. in front of and 8 ft. 2 ins. behind the frog point, as shown in Fig. 64. The Pennsylvania Ry. uses a 15-ft.

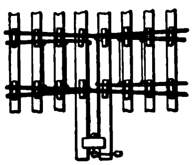


Fig. 63.—Movable Point Crossing.

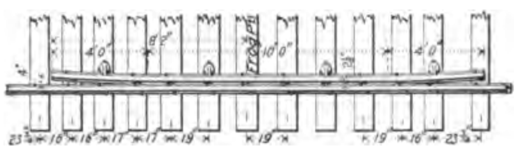


Fig. 64.—Frog Guard Rail; Norfolk & Western Ry.

guard rail, straight for 6 ft., at the middle, and then curved for 4 ft. 6 ins. to give a clearance of 7 ins. at the ends. This rail has 9 ft. 6 ins. in front of the frog point and 5 ft. 6 ins. behind the point. The Detroit, Lansing & Northern Ry. also uses a 15-ft. rail, with 1¾ ins. flangeway, but it is straight for 8 ft. and then curved to a radius of 16 ft. 6 ins. for 3 ft. 6 ins., giving an end clearance of 6½ ins. The ends of this rail are beveled off vertically from head to base for 6 ins. It will often be necessary to plane off the edge of the flange of the guard rail to enable it to be placed close enough to the track rail.

Foot Guards.

A large number of accidents to railway employees are caused every year by men getting their feet caught in the narrow space between a guard rail and track rail, or between the rails of a frog or switch, the men being unable to free themselves and being run over and either killed or maimed. Such accidents are especially common in yards. Wooden blocking, metal guards and gravel or cinder filling are employed, but are very frequently omitted, although some States have legislation requiring the use of such devices, but the railways and the track officials should insist upon their use. Frogs sometimes have cast-iron foot guards bolted in during manufacture, but as a rule, some portable guard is used. One

of these is an iron strap or bar of the same height as the rail web, bent back and forth into a double loop, and driven in between the rails, the bar being, of course, on edge. The National metal foot guard (National Railway Foot Guard Co., Columbus, O.) resembles a box open at the bottom and one end, being made of two pieces of sheet steel held together by two bolts and forced apart by spiral springs. When being put in place the sides are pressed together to allow the guard to be slipped in between the webs of the rails, and when released the springs force the sides closely against the rails; a spiké or brace at the heel of the guard prevents it from working out óf place. Owing to its flexibility it can be used at the heels of switches and in spring rail frogs. In the Green foot guard (Roberts, Throp & Co., Three Rivers, Mich.) there are two flat plates, one above the other, held apart by springs and connected at the heel, the upper plate being formed to fit the rail head.

Relation of Wheels to Frogs and Switches.

In 1885 the Master Car Builders' Association adopted as standard a distance of 4 ft. 5⅜ ins. back to back of wheel flanges, with a variation of 4 ft. 5½ ins. maximum and 4 ft. 5¼ ins. minimum. In practice, however, the result of carelessness or neglect is to leave in service wheels which are entirely unsuited to the gage of track at frogs and switches, being very damaging and destructive to frogs and guard rails, and being the probable cause of many "unexplained" derailments at these places. A variation of ½-in. in the clear distance between the wheels is sufficient for all reasonable inaccuracies in mounting wheels on axles, and although one objection which has been made to this is the expense and delay to traffic which would be caused by changes to cars now running with badly gaged wheels, it is probable that the number of such cars is insignificant as compared with the amount of damage caused by them, and that the saving in maintenance of frogs and guard rails would soon compensate for the expense of remounting badly gaged wheels. The trouble is aggravated by cheap contract-made wheels having thick and irregular flanges, which do not conform to the standard form adopted by the Master Car Builders' Association. It is also aggravated by the variations due to different forms of rail heads having large or sharp corners and vertical or inclined sides to the heads.

It is an expensive practice to keep engines in service with hollow or double-flange worn driving-wheel tires, as they are seriously destructive to frogs and switches, lead to much expense in track maintenance and repairs, and are liable to cause derailment, especially at spring rail frogs. The broad tires of blind or blank driving-wheel tires, when worn, exert a powerful bursting force on guard rails, frogs and switches, which parts are not designed to withstand such strains. The permissible limit for depth of wear of tires in regular service should be ⅛ to ¼-in. for road engines, and ¼ to ⅜-in. for switch engines. It is not of much use to distinguish between passenger and freight engines, as they are frequently used in similar service, but the ⅛-in. limit might well be set for engines run at high speeds. The roadmaster should have a tire gage and promptly report any engine whose tires are worn beyond the limit adopted on his road. This will tend to prompt the master mechanics to keep the engine tires in proper condition. The present limit of wear allowed by various railways ranges from ¼-in. to ⅜-in., though wheels worn ⅝-in. hollow are

sometimes met with in practice, the motive power or traffic department claiming (if any complaint is made of this) that the engines cannot be spared to go into the shops. Such tires on new rail with wider head than the old rail, will slip and throw the engine from side to side, to the detriment of the track and engine. The deep flanges, too, are liable to break the track bolts, and the limit of depth of flange should be 1½ ins. for road and 1⅝ ins. for switch engines. The latter engines are often allowed to run with tires in very bad condition, causing excessive wear of the rails and frogs and making it almost impossible to maintain the yard tracks in proper condition. Some roads insist upon the observance of the rule against a greater wear than ¼-in. on any engine, and this practice is to be well recommended, but on most roads there is no general rule, and the excuses that the engines cannot be spared, or that the turning is too expensive are allowed. It is, of course, a somewhat expensive piece of work to run an engine into the shops, take down the rods, get the wheels out and turned, and re-erect all the parts. On the other hand, this is required only occasionally, while the destruction of frogs and the excessive wear of track causes a continual drain on the maintenance expenses. Driving-wheel brakes with "tire dressing" brakeshoes, which bear on the whole width of the wheel tread and also on the flange, are a great factor in increasing the mileage of the wheels without causing undue wear on the track.

According to a report presented at the meeting of the Roadmasters' Association of America, in 1895, the damage to spring rail frogs from hollow tires consists mainly in battering and shearing off the wing and point. It is on this class of frogs that the greatest danger of derailment from hollow tires exists, for, in trailing the frog, the tendency of the hollow tire is to crowd the spring wing out; the gage is thereby widened and the result is a derailment. Again, each time an engine with hollow tires crosses a spring frog, a severe blow is delivered to both the point and wing rail; this, when given to the spring wing, after a time causes it to become bent or strained, which retards the free and natural action of the spring, so that the spring wing cannot be depended upon to close properly after the switch is used, and here is a danger of derailment, which may be traced to the hollow tire. The swing given to a locomotive with hollow tires, when running over a frog, causes the gage of both the track and guard rail to be affected, and the general line of the frog to become ruined, thereby necessitating frequent readjustment.

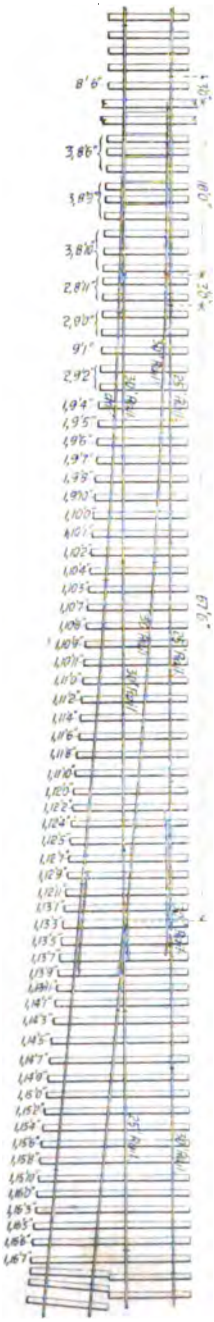
As a measure of safety, when hollow tires are allowed to run, the spring rail should be planed down where the tire first comes in contact with it; this will allow the wheel to mount the wing, without so great a chance of the wing being crowded out and the engine derailed. There should also be a flaring opening left at the point, as the flange would be started in before putting any pressure on the spring wing, thus relieving the guard rail. The damage to rigid frogs by hollow tires is of the same nature as to spring frogs, but the danger of derailment is not nearly so great. The effect of hollow tires on split switches is about the same as on spring rail frogs, there being great danger of derailment when a locomotive with badly worn tires trails through. If these switches were never used by engines with bad tires, it would not be necessary to elevate the point above the stock rail; but, under existing circumstances, the point should be planed down so that it is not less than ¼ in. lower than the stock rail

at the point, and rising gradually until it is not less than ¼-in. higher than the stock rail at a point where the planing of the head of the switch rail ends.

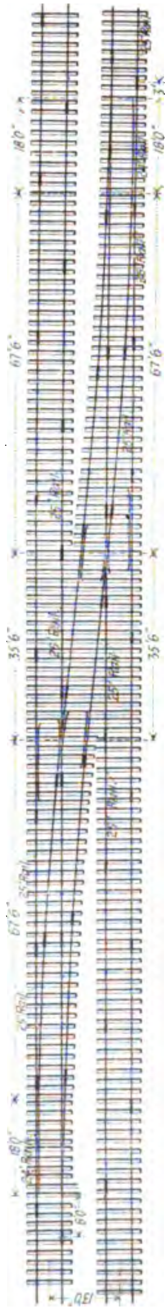
Switch Ties and Timbers.

The rails of turnouts may be laid upon sawed switch timbers or switch ties of varying length, carrying the main and turnout rails, as shown in Figs. 65 and 67, or upon ordinary ties alternating for the two tracks, as in the Boston & Albany Ry. practice, shown in Fig. 66. The former plan looks better, makes a more solid connection between the tracks, and is generally used; but some good roads prefer the latter plan. The long ties are somewhat difficult to renew, and have generally to be renewed in sets, while the alternated ties give a closer support to the lead rails. On the other hand, it is more difficult to tamp the separate ties to an even and uniform bearing. Switch timbers should be of the same thickness as the ties, and not less than 7 or 8 ins. wide on the face. Some roads have them 9 and 10 ins. wide, to give a good bearing to the curve lead rails, as the sharp curve makes them liable to cut into the ties along the outer edge of the rail base. It is better to prevent this cutting by the use of metal tie-plates, and great economy has been effected by their use, while they are also frequently used to replace rail braces on turnout curves. The timbers should be spaced about 20 to 24 ins. apart, c. to c., not less than 8 ins. apart in the clear, but the spacing must be varied to fit the rail joints and to get a tie under the frog point, or as nearly under as a yoked frog will permit.

The required length of the timbers is ascertained by taking the distance (in inches) between the tie at the heel of the switch and the tie under the frog point, dividing this by the number of ties to be placed between them, and adding the amount thus obtained to the length of each tie, starting from the heel of the switch. This arrangement, with every timber cut to length, is shown in the Erie Ry. turnout, Fig. 65. Very frequently, however, instead of using a different length for each timber, the timbers are made in groups of the same length to the nearest 6 or 12 ins., as shown by the bill of material for the Southern Pacific Ry., given below. Fig. 67 represents this latter plan as applied on the Southern Pacific Ry., and also shows the method of placing a split-switch in the track without cutting rails. The last long timber should not exceed 16 ft. in length, though for crossovers on double track the middle timbers are often made long enough to take both tracks. A practice sometimes followed is to have a plank about 1 x 10 ins., 16 to 18 ft. long, with the lengths of the several timbers scribed and marked upon it. This is used as a gage in sawing the timbers to length before laying, but it is better to have them sawed to specified lengths at the mill, if this can be done. To ascertain the length of timbers for a three-throw switch, subtract half the length of the standard tie from the length of the switch timber for a single switch, and then multiply the remainder by two. Most roads have fixed tables or bills of material for switch timbers, which are issued to the foremen. The arrangement of ties at track crossings will be found in Chapter 9, under the heading of "Track Crossings." The ties or timbers should be carefully laid on good, well drained ballast, and firmly tamped, especially under the frog, except that where plate frogs are used the ties may be set a little low, or allowed to settle, to allow for the thickness of the



(Turnout for 80-lb. Rail.)



(Crossover for 80-lb. Rail.)

Fig. 65.—Arrangement of Switch Timbers; Erie Ry.

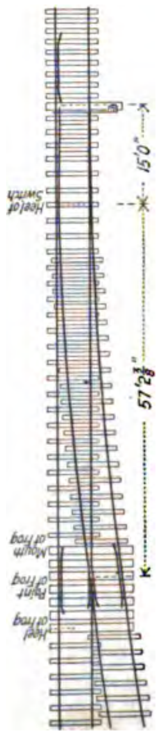


Fig. 66.—Turnout Laid on Ordinary Ties; Boston & Albany Ry.

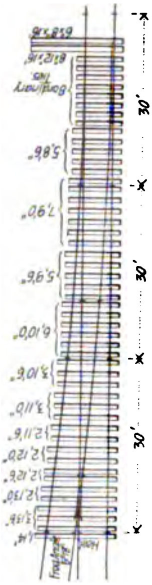


Fig. 67.—Turnout Laid on Switch Ties; Southern Pacific Ry. (Showing also the Method of Placing a Split Switch in the Track without Cutting Rails.)

plate. This is better than cutting the ties for the plate. In table No. 12 are given examples of bills of material for switch timbers:

TABLE NO. 12.—BILLS OF TIMBER FOR SWITCHES.

Bill of Timber; Southern Pacific Ry.

(No. 7 Frog; tracks, 15 ft. c. to c.; ties, 26 ins. c. to c.; all timbers 7 x 10 ins., except two 4 x 12 ins. for turnout, and four 4 x 12 ins. for crossover.)

Turnout.			Crossover.		
No. of pieces.	Length, ft.	Ft., B. M.	No. of pieces.	Length, ft.	Ft., B. M.
18	10	758	26	10	1,517
11	12	770	22	12	1,540
7	14	571	14	14	1,143
7	16	653	6	16	560
6	18	630	10	24	1,409
2	18	252	4	18	504
46		3,634	82		6,664

Bill of Timber for No. 10 Frog; Philadelphia & Reading Ry.

(All timbers 7 x 9 ins.)

Turnout.								Crossover.			
No. of pieces.	Length, ft.	ins.	Feet, B. M.	No. of pieces.	Length, ft.	ins.	Feet, B. M.	No. of pieces.	Length, ft.	ins.	Feet, B. M.
1	16	0	84	2	13	3	140	2	16	0	168
6	8	9	276	1	13	6	71	12	8	9	552
6	9	0	284	2	13	9	144	12	9	0	568
5	9	3	243	1	14	0	73	10	9	3	486
3	9	6	150	2	14	3	150	6	9	6	300
3	9	9	154	1	14	6	76	6	9	9	308
2	10	0	105	2	14	9	154	4	10	0	210
2	10	3	108	1	15	0	79	4	10	3	216
2	10	6	110	1	15	3	80	4	10	6	221
2	10	9	113	1	15	6	81	4	10	9	226
2	11	0	116	2	15	9	165	4	11	0	231
2	11	3	119	1	16	0	84	4	11	3	238
2	11	6	121	2	16	3	170	4	11	6	242
2	11	9	123	1	16	6	86	4	11	9	247
1	12	0	63	2	16	9	176	2	12	0	126
1	12	3	64	1	17	0	89	29	20	9	3,161
1	12	6	65	1	17	3	90				
2	12	9	134					111			7,500
1	13	0	68	70			4,408				

Switchstands.

The switchstand contains the apparatus for operating the switch, and in general it consists of a frame carrying a vertical shaft (or horizontal for some yard switches) with a double target at the top, and a horizontal crank at the bottom, the switch connecting rod being attached to this crank. The shaft is turned on its axis by means of a hinged lever, which normally hangs vertical, but is raised to a horizontal position when the switch is to be thrown. This lever is then swung round, turning the shaft and crank and throwing the switch. This is the operation of the switchstands shown in Figs. 68, 70 and 71. In some cases the crank is replaced by a bevel gear rack and segment, while in others the lever operates a segmental spur gear at the top or base of the frame of the switchstand. In the latter case the crank shaft and target shaft are two separate rods, connected by the horizontal gears keyed to them, and the lever is attached to the target shaft. With the steady increase in the use of the block system and interlocking plant, there is a more general use of the interlocking system in yards, especially in passenger yards and at the entrance to freight yards. In such cases the switches are operated from levers concentrated in a tower, but the subject of interlocking is too broad to be dealt with here, and only the ordinary independent switchstands operated by hand are referred to in this chapter.

Main line switches, whether interlocked or not, should be connected with distant signals, but where these are not used the switchstand should

be high, carrying the targets and lamps 6 or 8 ft. above the rail level. Where a main line switch is on a curve or liable to be hidden by cars, etc., at a station or yard, it is well to connect it with a distant target or semaphore signal, about 1,000 to 1,200 ft. distant, so as to give the engineman timely warning as to the position of the switch. The Illinois Central Ry. places a semaphore signal 1,200 ft. from the switchstands of outlying switches.

For main switches as at yard entrances, etc., where distant signals are provided, it is most important that the signal cannot be made to show clear before the switch is properly thrown. One of the simplest means for

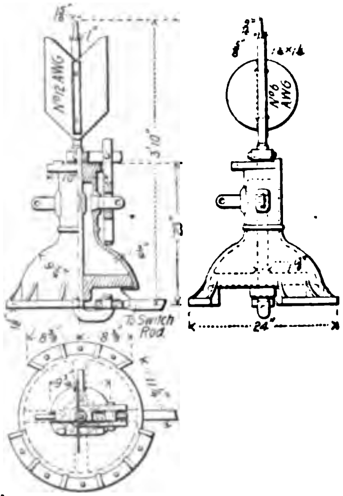


Fig. 68.—Low Switch; Illinois Central Ry.

this is to use a double-lever switchstand, with levers so interlocked that the switch lever must be fully reversed and the switch rails brought properly home before the signal lever can be operated. In addition it should be necessary to reverse the signal first, before the switch can be thrown.

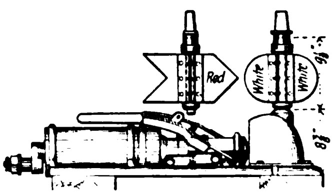


Fig. 69.—Horizontal Switchstand; Norfolk & Western Ry. (Ramapo Style).

Ordinary yard switchstands should be from 4 to 5 ft. high from the rail, while low ground or dwarf stands, about 2 ft. high, may be used in yards, these latter sometimes being horizontal, as shown in Fig. 69. Where two or three switches near together open out from a main track connection the switchstands should be set at varying distances from the rail, so that the targets will not be in line, or should have the targets at varying heights, gradually diminishing from that at the first switch.

The Illinois Central has three standard sizes: 3 ft. 10 ins., 5 ft. 5 ins., and 7 ft. 1⅛ ins. high to the top of the rod (exclusive of the lamp). Where three switchstands come in line at one end of a station, the low stand is used for the first or outer switch; then the medium and then the high stand. Where two switchstands come in line, the medium is used at the outer and the high stand at the inner switch. These stands have a white disk and a red target, as shown in Fig. 68. On the high stand, the disk is 17½ ins. diameter, of No. 16 A. W. G. steel; the red target is 30 x 12 ins., of No. 12 steel. The Norfolk & Western Ry. high stand is 7 ft. 5⅛ ins. from the tie to the top of the rod, and has an oval white target ⅛-in. thick (No. 10 iron), 12 x 8½ ins., made in two pieces, flanged and riveted; the red target is 24 x 12 ins., rectangular, with a 6-in. fishtail notch. The stand has switch rods 1½ ins. diameter, target rod ⅞-in. square, and a throw of 3¾ ins., the distance from center of shaft to center of pin being 2⅝ ins. The lamp has 5⅝-in. lenses. The medium stand is 3 ft. 11⅞ ins. high to the top of the shaft. The medium, low and pony (horizontal, Fig. 69), switchstands have

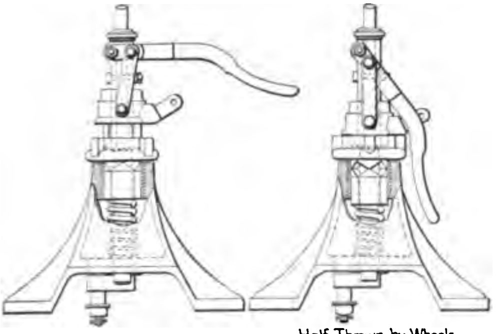


Fig. 70.—Ramapo Automatic Switchstand.

white oval targets, 6 x 10 ins., and red targets, 6 x 12 ins. The Great Northern Ry. uses a high stand 8 ft. 10 ins. high to the top of the lamp fork, with a white target 12 ins. wide, on which is painted a 9-in. red disk. The target for the turnout may be shaped to indicate to which side the switch leads. On double track the back of each target may be painted black.

A simple device for unimportant yard switches is a tumbling lever or drop lever switchstand, Figs. 49 and 50, operated by a lever lying on the headblock, so as to be out of the way. These very often need not have targets, and if little used they may be fitted with padlocks. Such switchstands are sometimes even used (but most improperly) for main line switches, being operated by a weighted lever which must be held up to keep the switch set for the sidetrack, but this is a very poor method, especially as the lever may be propped up by a careless or lazy trainman or switchman. Underground switchstands are used abroad to some extent and have the advantage for yard use that they offer no obstructions to be tripped over. One form has an iron box sunk in the ground, with its top flush with the surface. An inverted T rocking lever inside has a stirrup handle at the top, passing through a slot in the cover of the box, and the switch rod is

attached to this vertical leg. A heavy weight rolls along the lower leg, so that the switch must be fully thrown one way or the other by the weight rolling down the incline of this leg. Many accidents have occurred through men neglecting to close the switch after a train has entered or left the sidetrack, and to prevent this the New York, New Haven & Hartford Ry. had at one time an arrangement by which the man had to go into a switch house and close the door before he could set the switch for the sidetrack, and then could not open the door until the switch had been reset for the main track. Devices for this same purpose have been patented again and again, but are of little use. Where a distant signal is used, the switch lever (working like a signal lever) may be so arranged that the first half of the throw operates the signal and the last half operates the switch; thus the switch cannot be opened for the sidetrack until the signal has been thrown to indicate this position, and must be closed before the signal can be cleared for the main track.

To allow for trains trailing through a closed switch without injury to the switch, an automatic or safety switchstand is very generally used. This may be made so that the switch can be trailed through from either one track when set for the other track, or it can be made with a rigid connection when set for the main track, so that a train from the sidetrack trailing through it in this position will break the connections and show that the switch has been misused, as it is a dangerous practice to allow trains to run thus through a switch set for the main track. The switch is usually operated by a hinged lever which hangs vertically, engaging with one or other of two lugs or notches in the frame of the switchstand. To throw the switch, the lever is raised to the horizontal position, which brings it clear of the lug, and is then pulled round in a horizontal direction until it is in position to engage with another lug. The lever cannot be pulled far enough to engage with the second lug unless the switch rail is home against the stock rail, so that any obstruction will at once be evident. In the Snow or Ramapo automatic switchstand, Fig. 70 (Ramapo Iron Works, Hillburn, N. Y.), the upright rod or shaft is in two pieces, with a clutch connection and spring. This gives a direct and rigid connection when worked by hand, but when worked automatically by a train the connecting rod turns the lower part of the shaft, compressing the spring and pulling down the lower jaw of the clutch, so that it can turn without affecting the upper part of the shaft, which is locked. The spring closes the clutch connection as soon as the pressure of the wheel frees the switch rail and connecting rod. There are various styles of automatic switchstands, generally having a combination of clutch and spring, but in the Weir switchstand the clutch is done away with, and two horizontal springs connect with the lever casting on the shaft. The automatic switchstand is much safer than the automatic switch (Fig. 49), as the latter can have the lever locked even when the switch rails are not fully thrown, as already described, while in the automatic switchstand this cannot be done, and they should have such connection between the switch rails and target that the latter will invariably indicate the position of the switch. While there are certain places where the use of automatic switchstands is admissible and while they are very generally used, the best practice is to adopt a rigid stand, and to forbid the practice of running through closed switches; and this is the safer and more reasonable plan. The Weir rigid switchstand (Weir Frog Co., Cincinnati) is shown in Fig. 71.

The switchstand is carried on one or two long ties, called the headblocks, so as to be kept immovably fixed in relation to the switch, but for high switchstands the shaft carrying the lamp and target is frequently supported by collar bearings on a vertical braced post or a set of three or four inclined rods, the post or rods being fitted to a framed foundation independent of the headblock. In this way the lamp is relieved from some of the shock and jar incident to the operation of the switch. The switch-

Fig. 71.—Weir Rigid Switchstand.

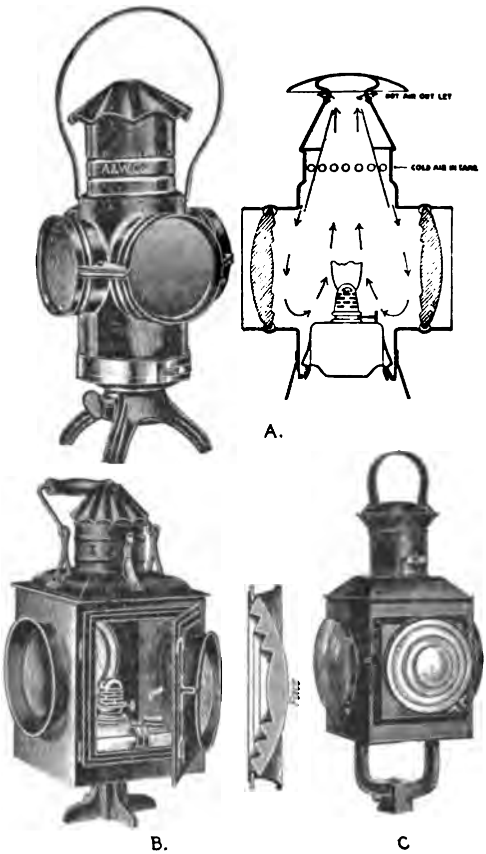


Fig. 72.—Switch Lamps.

stand should be firmly bolted to well tamped headblocks, and no lost motion should be allowed, while the working parts should be kept true, clean and well oiled.

The targets are usually of sheet iron (No. 10 to No. 16 American wire gage) of square, diamond, circular or other shape. The two targets for

the two tracks governed by the switch should be of as distinct shapes as possible, and should be kept clean and well painted, as in gloomy weather, or with smoke and steam blowing across the track, an engineman may easily mistake what he can see of a dirty red square to be a dirty white disk. The stands for three-throw switches should have targets indicating for which track the switch is set. The targets should not be too large, or they will be a danger to brakemen hanging on the sides of the cars, and some of the horizontal arrow targets are very objectionable in this respect. On low stands or pot signals the targets may be attached to the sides of the lamp case, or to a rod rising above the lamp. As to the color of the targets, it has been shown by experiment that plain red and plain white are the most distinctive, and can be seen at the greatest distance. A black spot on the white does not make it any more readily distinguishable, and any white on the red tends to make it appear pink and consequently less bright and prominent. With a background of snow the white target may not be very clear, but the red one will be very prominent. Red and white are most commonly used, though some roads use green and white for the targets of yard switchstands. As vermilion paint is expensive, a bright red chromate of lead paint may be used and applied more frequently, and the colors are practically the same after a little exposure. If the switchstands are painted white, or whitewashed, their positions will be more easily seen by the enginemen, and the same applies to the signal posts of block signals. Enameled iron targets have been tried with good results on the Grand Trunk Ry.; they do not catch the dirt, do not fade, and are easily cleaned. The high stands for main track switches on the Richmond, Fredericksburg & Potomac Ry. have a circular target for the main track, and a fixed red and white arm like a semaphore blade for the sidetrack. On the Pennsylvania Lines West of Pittsburg, the main line switchstands are connected with standard semaphore signals, the running face of the blade being yellow, with a black band; and the back face white, with a black band. This is good practice in view of the fact that the semaphore is practically the standard form for block signals, and the same practice should be followed where interlocking plants or distant signals are used.

The switch lamps should be of good construction, sheet steel or galvanized iron being usually preferable to tin. They are either square or round, and have generally hinged doors, which are preferable to slides. In some cases there is no door, the oil pot being removed, put in and taken out from the bottom of the case, while in some of the round lamps the top is hinged to swing open. Side doors and slides should be air tight, and the ventilating openings so protected that the light cannot be blown out by the wind. In the Adams & Westlake lamp, the Watts upper draft system is employed, the air supply being taken above instead of below the flame, as at A, Fig. 72. Kerosene is generally employed for the lamps, and chimney glasses are not often used. There should be a peep hole and wick raiser in the outer case, so that the lamp can be inspected and trimmed without opening the door. A spring bottom is also sometimes used to prevent the wick from being shaken down by the jarring of the switchstand. The lenses should be of ample size and good design, so formed as to throw a direct beam of light of the greatest intensity, and not a diffused light. The lenses may be of plano-convex form (flat at the back and spherical on the face), but the best form has the back cut in concentric corrugations,

as shown at A and B, Fig. 72. In some cases, however, the corrugations are on the face of the lens, as at C, Fig. 72. The ordinary size of lens is 4½ to 5⅜ ins. for main line switchstands, and the larger size is preferable. A diameter of 8 to 8⅜ ins. is sometimes employed for lamps at signals, tunnels and crossings. The lamps for yard switches may use 4-in. lenses; and those for dwarf signals, 3-in. lenses; while backlights may be 2 ins. diameter.

To ensure the lamp being in proper position on the switchstand, the socket or fork should be so shaped that the lamps can be put on only in one position. If a socket on the lamp fits on top of the vertical shaft of the switchstand, one corner of the socket may be filled up to fit a chamfered corner of the rod. The lamps should be kept clean, in good repair and properly trimmed, the lenses especially being wiped free from grease and dirt. The wick should rarely be cut with scissors, but the crust on its top may be removed by the fingers or a match stick. The light should be turned down as soon as lighted, and then gradually turned up to give the proper size of flame, being watched for a few moments to see that it burns steadily and does not flare or smoke. When the light is extinguished the wick should be turned down to prevent waste of oil. If the lamps are carried lighted from the section house they should be examined after being put in position on the switchstand. The filling and trimming of the lamps should be done on a shallow zinc lined tray or shelf with raised edges to prevent waste of the oil, and the oil cans may be set on a shallow tray filled with sand, to prevent the floor from getting greasy. The lamps are usually kept lighted from sunset to sunrise, and during foggy weather.

Red and white are the colors most generally used for switch lights (see Fig. 49), while some roads use green and white for yard switches. There is, however, a growing tendency to use green instead of white as the clear signal for main track, and this is a very desirable change, as station lamps, street lights, etc., are not unlikely to be confused with the switch lights, especially at yards in towns. Besides this there is the possibility of a broken red lens causing a white light to be shown. Some roads, therefore, use red and green, the lamps showing a green light in each direction when the switch is set for the main track, and a red light in each direction when the switch is set for the side track. On the Boston & Albany Ry., there is a white target and a green light shown when the switch is set for the main track, and a red light and target when it is set for the side track.

CHAPTER 8.—FENCES AND CATTLEGUARDS.

Fences.

The numerous styles of fence in use by railways are due to local conditions, to the varying ideas of engineers and officers, and to the laws of different states. Some of these laws specify the style of fence more or less in detail, while others merely require the use of a fence that will turn stock. One of the oldest forms of fence, still largely in use, though rarely built by railways, is the familiar snake fence; the objections to this are that it occupies considerable space, and is easily scaled or broken down, while its appearance is very unsightly. All fences should be at least 4 ft. 6 ins. high.

Wooden Fences.—The most common forms of wooden fence now used are the post-and-rail and post-and-board patterns. With a rail fence the posts are slotted to receive the ends of the rails, which are usually irregular sticks, more or less straight, having the ends adzed flat to fit into the slots, where they either lie loosely or are secured by pins through the post. The board fence, however, is by far the more common, and has flat boards or planks nailed to the posts. Oak, tamarack, cedar and chestnut are used for fence posts, the two latter being the more durable. They are usually 7 to 8½ ft. long, 6 to 6½ ins. diameter at the large end, and 4 to 5 ins. at the small end. They should not be split, but left round, stripped of bark, and may be pointed if they are to be driven, but this is not necessary where they are set in post holes. It is best to put the larger end downward. The posts should be not less than 2½ or 3 ft. in the ground, and may be driven by mallets or a small pile driver mounted on wheels; or they may be set in holes made by long-handled shovels or post-hole augers or diggers. If the hole is 24 ins. deep and the post is driven 12 or 18 ins. deeper, and the earth then well rammed and tamped into the hole, the post will be very secure. The tops should be cut off square at a uniform height above the ground, the height being gaged by a stick having a flat board at one end. The posts are usually spaced 8 ft. c. to c. If the ground is heaved by frost and throws the posts out of line and partly out of the ground, as is specially the case in clay soil, the soil should be dug away, the posts redriven and the earth tamped in again. Fences have sometimes to be built on rocky or swampy ground where posts will not hold, and in such cases the posts may be mortised into sills 4 ft. long, made of old ties cut in half, and secured by braces nailed to the top or side of the sill and back or side of post. Rough A-frames made of posts may also be used.

The boards are generally of pine, hemlock or other cheap wood, 16 ft. long, 1 or 1¼ ins. thick, and 6 to 12 ins. wide, 6 or 8 ins. being preferable. They should all be of the same size, the bottom boards being placed closer together than the upper ones so as to stop small stock. The boards are placed on the field side of the posts, and each is secured by three or four 10 or 12 penny (4-in.) nails, while occasionally the posts are notched or boxed out ½-in. for the boards. If all the joints come on the same posts, a batten, 1 × 6 ins., the height of the fence, may be nailed on the field side of the boards, covering the joints, but in general the joints are broken, and

come on alternate posts. Five boards are usually sufficient, and in some cases a cap board is laid flat on the tops of the posts and spiked to them. When this plan is adopted the top board may or may not be used, but in the standard board fence of the Michigan Central Ry., Fig. 73, a cap board and top board are both used. It is not often that a bottom board is used on the ground, as shown here.

Wire Fences.—These have come into extensive use on account of their efficiency, safety from fire, and small amount of maintenance required. They are of two kinds, woven fencing and strand fencing, the former being a network of coarse mesh, and the latter having independent horizontal strands of plain, barbed, twisted or ribbon wire. The wire used weighs about 345 lbs. per mile, or 6½ lbs. per 100 ft. The posts may be 8 to 16 ft. (or even 33 ft.) apart, 15 ft. being a good spacing, and four or more wires may be used as required, the lower wires being closer together than the upper ones. It is always best to use a top board or cap board, or both, so that animals may see the fence more clearly, especially in cloudy or foggy

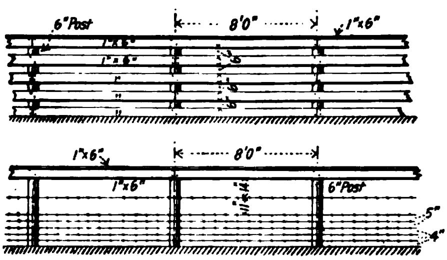


Fig. 73.—Board and Wire Fences; Michigan Central Ry.

weather, and so be prevented from running against the wire and being injured. Some roads use a top board or rail 2×4 ins. with the tops of the posts cut at an angle of 45° upward from the track or field side of the post. The standard wire fence of the Michigan Central Ry., Fig. 73, has six wires, a top board and a cap board. At the starting end of each length of fence, the wires are secured to a strongly braced anchor post, and in order to allow of taking up the slack and sag of the wires, their free ends are attached to spools in an iron post or to some other adjustable fastening by which the wires may be wound up and tightened. To prevent the wires from pulling the posts over, some of the posts (say, at every fifteenth or twentieth panel of 15 ft.) must be braced. The braces may be of plank, or a 3×5-in. stick, having one end let into the top of the post, and the other end let into the next post at the ground line or into the top of a stake driven into the ground between the posts. Posts may also be braced by a stout wire wrapped around the top of the post and carried down to and wrapped around the two adjacent posts at the ground line. Gate, corner and end posts must also be well braced and anchored to ensure their maintaining a vertical position. The strands are usually attached to the posts by wire staples (70 or 75 to the pound), and for long panels they may be stapled to a batten at the middle of each panel, so as to keep the wires evenly spaced and prevent them from sagging.

The standard wire fence of the Fremont, Elkhorn & Missouri Valley Ry., Fig. 74, has 16-ft. panels, with five lines of barbed wire, spaced 5, 7, 10, 14 and 18 ins., and has no top board. The fence of the Canadian Pacific Ry., Fig. 75, has four wires, a top board, and an inclined cap board. The posts are of round cedar, not less than 5 ins. diameter at the top,

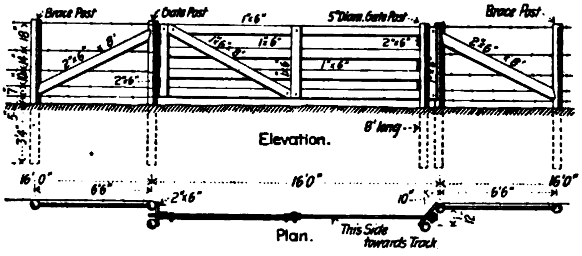


Fig. 74.—Wire Fence and Farm Gate; F., E. & M. V. Ry.

straight and peeled. The wire has barbs not less than 6 ins. apart, and is stapled to the posts. The boards are nailed to each post with six 4-in. cut nails, and braces are put in at intervals of 300 ft., notched 1½ ins. into the posts and secured by 40-penny nails. Fig. 76 shows the styles of fence used by this road on rocky ground, the vertical post style having four

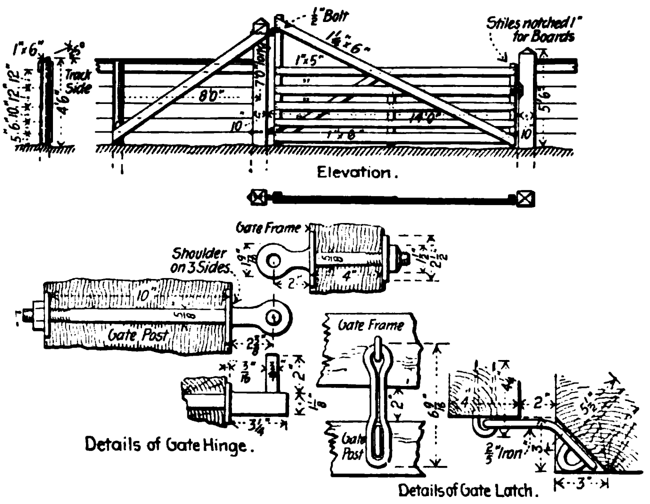


Fig. 75.—Wire Fence and Farm Gate; Canadian Pacific Ry.

wires, and the A-frame style five wires. The wire fence of the Louisville & Nashville Ry., in Kentucky, has posts 7 ft. long, 10 ft. c. to c., with seven wires, spaced 4, 4, 6, 8, 10, 12 and 12 ins. The three lower wires are of barbed hog wire. The four upper wires are of barbed cattle wire, except where there is danger to stock, in which case the two top ones are of

plain ribbon wire. The estimate for this fencing, for one mile of one line of fence, is as follows:

	Quantity, per mile.	Cost, per mile.
2 plain ribbon wires, 6.66 lbs. per 100 ft.....4 cts. per lb.	704 lbs.	$28.16
2 barbed cattle wires, 7.14 lbs. per 100 ft...2.8 cts. per lb.	754 "	21.07
3 barbed hog wires, 7.69 lbs. per 100 ft.....2.8 cts. per lb.	1,218 "	34.11
Staples ....5.5 cts. per lb.	49 "	2.70
Posts, 10 ft. apart ....20 cts. each.	528	105.60
Bracing, yellow pine boards, 1 x 6 ins. ..$12 per M. B. M.	...	5.28
Labor	...	105.60
Total		$302.52

The Michigan Central Ry. uses a wire fence with panels 8 ft. long, six wires, a top board and a cap board. The wires are spaced 4, 4, 4, 5, 5, 11 and 14 ins.; the bottom wire is 4 ins. from the ground, and the close spacing is to prevent sheep and hogs from getting through. Hogs are very difficult to turn, and sheep will often get through a barb wire fence which seems impassable. A special fence for keeping back hogs may have a bottom wire, then two boards, and then two, three or four wires and a top board, according to the other kinds of stock. The Iowa Central Ry. standard fence has five stands of barbed wire on posts 16 ft. apart, and the wing fences at road crossings have five boards, 1 x 6 ins., 16 ft. long, run-

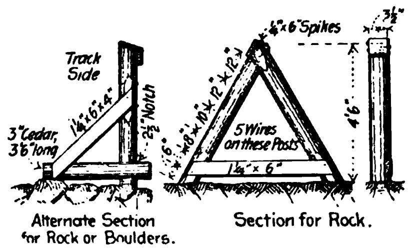


Fig. 76.—Fence Posts for Rocky Ground; C. P. Ry.

ning to the cattle guards and painted white. This fencing cost $235 per mile complete, or $117.50 for each side of the track. The cost per mile for 60 miles of wire fencing on the Manitoba & Northwestern Ry., in 1887, was $167.38, and the farm gates cost $8 each. The posts were of round oak or tamarack, cut square at one end and pointed at the other; they were 5 ins. diameter at the small end, 8 ft. 6 ins. long, driven 3 ft. 6 ins. into the ground by a small pile driver mounted on wheels, and were placed 16 ft. 6 ins. apart; the posts carried four wires, spaced 12, 14, 15 and 16 ins., making a fence 4 ft. 9 ins. high; the items of cost were as follows:

350 posts (including braces)........................	10 cts. each.	$35.00
1,500 lbs. barb wire, four-pointed.....................	6 cts. per lb.	90.00
40 lbs. staples	6 cts. per lb.	2.40
Labor		36.86
Freight, superintendence and tools		3.07
Total cost per mile		$167.38

Woven wire fencing of large mesh is being extensively used in railway work, and is especially advantageous for small stock, but unless well made and well hung it is liable to sag and bulge, becoming very unsightly. The McMullen fence, Fig. 77 (McMullen Woven Wire Fence Co., Chicago, Ill.), is used quite extensively, and resembles ordinary garden fencing, but has a mesh of 5½ x 10½ ins. as a rule, though a mesh of 6½ x 14 ins. is sometimes

used, but this is too large for a good fence. The width is 47½ to 53 ins. Steel wire of No. 13 or No. 14 gage is used as a rule, being galvanized before weaving, and there is a twisted wire rope selvage at the top and bottom. The cost is about 25 to 35 cts. per lin. ft. This fencing has been used along tracks running through suburban streets, being neat and unobtrusive in appearance. The posts should be 12 to 16 ft. apart, and a nail should be driven in each post at the level of the top of the fence. In erection, the netting is first fastened firmly to a straining post or anchor post, the selvages and intermediate wires being stapled to the post, care being taken to keep the meshes square with the post and not to stretch the web too wide. It is then unrolled and hung on the nails by its top selvage. The top selvage is first drawn tight by a ratchet stretcher and stapled for about 200 ft.; and then the bottom selvage is treated in the same way, the meshes being pulled square by hand and stapled to the posts. The Page fence, Fig. 78 (Page Woven Wire Fence Co., Adrian, Mich.), has rectangular meshes composed of continuous longitudinal wires variously spaced, and connected by vertical wires twisted around them. The special feature of this fence is that the longitudinal steel wires are first coiled

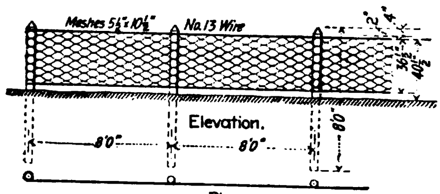


Fig. 77.—McMullen Woven Wire Fence: F., E. & M. V. Ry., Station Parks.

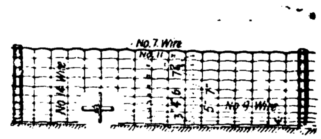


Fig. 78.—Page Woven Wire Fence.

round a ¾-in. rod, forming spiral springs which are then pulled out straight and connected by cross wires of annealed galvanized wire, twisted round each horizontal wire, and spaced about 12 ins. apart. The effect of coiling the wires is to give them a spiral twist, so that any tendency to slack or sag is taken up by the spring of the wires, while this arrangement gives the fence an elasticity that will resist stock pushing against it, the "spring" being sufficient to throw down an animal that may run against the fence. The wires used are generally No. 7 or No. 9 for the top, No. 9 for the bottom, No. 11 for the intermediate, and No. 14 for the vertical wires. The fence is delivered in rolls of 20 to 40 rods, weighing 11 lbs. per rod, and the panel length may be as much as 30 ft., if desired, but 16 ft. is preferable. The most effective height is 4 ft. 10 ins. In erecting, a stretcher is used, by which a strain of 5 tons can be put on the end, a full roll of 40 rods being stretched at one pull, so that a strongly braced end post is needed.

The Barkley & House fence has seven No. 9 galvanized wires, with galvanized wire stay-guards or flat spacing pieces between them, the guards being staggered and not continuous from top to bottom. While the flat pieces resist tension they are easily bent by compression or side blows, but this style of fence is much used in states where barbed wire is prohibited. The ends of the wires are on stretchers in the straining post, and can be tightened up at any time, the wires not being stapled tight to the posts but allowed to play freely in the staples. The Betts fence (Betts Fenc-

ing Co., Palmer, Mass.), consists of six No. 11¼ galvanized wires stapled to pine pickets about 1 ft. apart, the pickets reaching above the top wire so that animals will not lean their heads on the fence and so break it down. The fence is delivered in rolls of 100 ft., and is fastened to posts 12 to 16 ft. apart.

Fence Wire Stays and Tighteners.—Where fences with horizontal wires are used it is very often necessary to take up the slack of the wires, and it is not always practicable to do this by the ordinary end stretchers in the straining or anchor posts. One plan is to loop vertical stays to the horizontal wires and the Barkley stay is shown in Fig. 79. This is easily at-

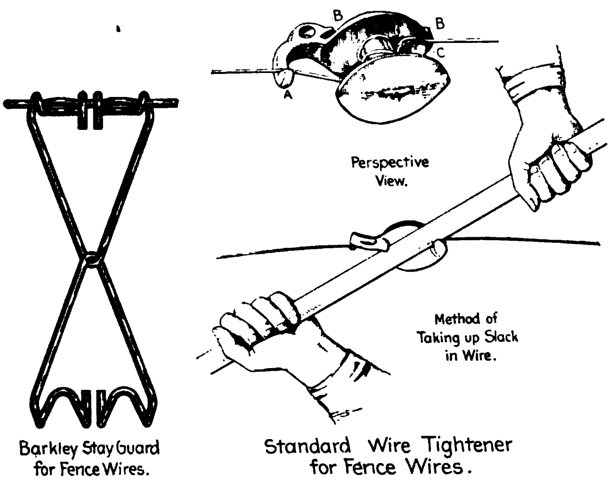


Fig. 79.—Fence Wire Tighteners.

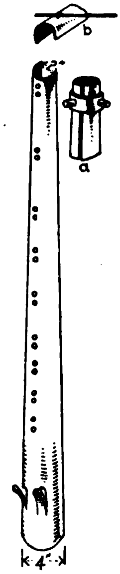


Fig. 80. Avery Iron Fence Post.

tached by means of a special wrench. It is made by J. J. Barkley, of Chicago. Another plan is to wind up the slack wire on a tightener hitched to it at the lowest part of the sag, and the Standard tightener of this class is also shown in Fig. 79, this device being made by the Standard Wire Fence Co., of Syracuse, N. Y.

Metal Fence Posts.—These are coming into somewhat extensive use, on account of the increased safety against fire. Many of them are of steel plate about ⅛-in. thick, 7 or 8 ft. long, and pressed to form a sort of circular or V section, with holes, slots or notches for the wires or staples. The bottom may have flanges or projections to anchor the post firmly in the ground, and the end posts may have anchor plates or braces, and may be braced to the adjacent brace posts, 8 ft. distant, by horizontal braces of 1-in. gas pipe. In some cases the posts can be driven without digging post-holes, a temporary cap being put on to receive the blows of the maul. The Avery post, Fig. 80, is of semicircular section, tapering to the top, and has prongs stamped out of the bottom to give it a firm anchorage. For end posts, two line posts are placed together and connected by collars,

as shown at "a." the collars having pins to fit into horizontal gas pipe braces. similar collars being fitted on the adjacent posts. The method of attaching the wires by staples in the holes is shown at "b." It is made by the Avery Stamping Co., of Cleveland, O. Light posts of angle iron or T-iron are used for lawn fences at stations, etc.

Gates.--The gates should be not less than 15 ft. wide in the clear, with gate posts in addition to the posts of the adjacent end panels. They are usually of fence boards, of the style shown in Fig. 74, and should be properly braced. This gate slides back for half its length and then swings round, and in some cases such gates slide back for their whole length, parallel with the fence. The gate shown in Fig. 75 is of better design, and is well supported against drooping by the long brace. The hinges and latch are clearly shown. Iron framed gates are sometimes used, a simple form being made of a 1½-in. gas pipe, bent in the shape of a Z, laid on its side, with the vertical legs against the gate posts, and a strap iron or rod brace riveted across each of the two loops. The diagonal part should incline upwards from the bottom of the hinge leg, this leg passing through bolts in the gate post, and having two collars, which rest on the eyes of the bolts and support the gate. Across the Z-frame may be strung lines of barbed wire or a woven wire netting. A swing gate should have strong hinges, well secured, and should be set so as to swing easily. It is a good plan to hang the gates so that they will close by their own weight after having been opened, as farmers are frequently very careless about the gates, but even if made in this way there is a liability of their being propped open. A sheet iron sign, lettered "Close the Gate" may be attached to the gate. Track walkers should be on the look out for open farm gates, and report any that may be habitually left open, as accidents have frequently been caused by cattle straying onto the track through an open gate, and in such cases a country jury may award damages to the farmer, in spite of the fact that the railway was properly fenced and the farmer himself was really responsible for the accident.

Hedges and Walls.—Hedge fences, as used in England, form a good looking and almost impregnable fence, being far superior to a barb wire fence in this latter respect. In this country they are rarely seen and are not very efficient. The Pennsylvania Ry. has some hedges of osage orange; the bushes have a youthful growth in about three years, but they are thin, weak and straggling, practically useless as fences, and in no way resemble the thick dense hedges characteristic of English railways. The best English hedge fences are made of thorn quicks, about three years old, which are obtained from landscape gardeners, and have previously been transplanted frequently. These are made up in bundles of about 1,000, and care is taken to protect them from frost from the time they are shipped (in October) until they are planted (in November or December). The ground is well dug by hand, and the quicks are planted singly, about 4 ins. apart, sometimes staggered in two rows about 6 ins. apart, but single rows are generally found to be satisfactory. They are allowed to grow without cutting until the stumps are 1 to 1½ ins. diameter, which takes about 8 years, and then they are topped or clipped to the required height. In cutting and trimming the thorns are cut upwards. The annual growth is about 1 ft., and this is cut off in the late spring or early summer. The thorns thrive best in heavy land, and are usually failures in light gravelly or sandy soil. In autumn or winter the ground is turned over for about

2 ft. on each side of the hedge, to prevent damage in case of sparks setting fire to the grass on the slopes, and this is also beneficial in giving air to the plants. In this country, in districts where field stones and boulders are plentiful, dry rubble walls are sometimes built, but as a rule they are not very stable and soon get more or less broken down.

Station and Yard Fences.—Brick walls and high board fences, with vertical or horizontal boards placed close together, are frequently used at station yards. Picket fences or neat (and more or less ornamental) iron railings or fences are often used at passenger stations, around the grounds or to prevent persons from crossing the tracks, especially where there are separate tracks for through and local trains. A cheap picket fence may have posts 5 x 7 ins., 10 ft. apart, with two triangular rails (cut from a stick 4 x 4 ins.) let into V-shaped notches in the posts. To these are nailed pickets, 1 x 3 ins. or 2 x 2 ins., with pointed tops, the pickets being 2½ to 4 ins. apart. The Pennsylvania Ry. uses a fence between tracks at way stations, having pickets 1⅝ ins. square, 4 ft. long, 6 ins. apart, on rails 3 x 3 ins., the ends of which rest in iron sockets attached to the posts, so

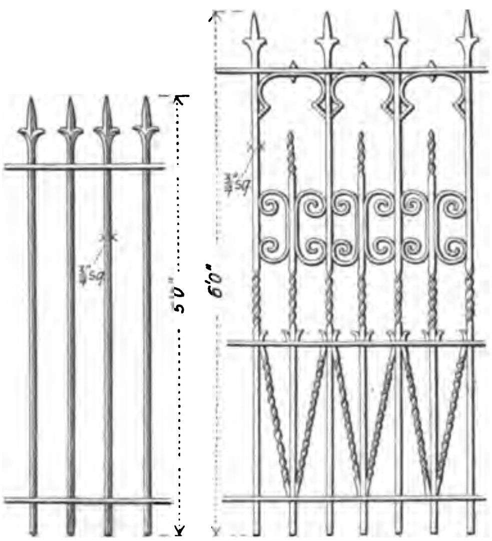


Fig. 81.—Iron Fencing for Stations, Etc.

that the panels can be lifted out when track repairs are going on, or to allow room for attention to hot boxes or the running gear of trains standing at the station. The posts are 4¼ ins. square, 10 ft. 1¾ ins. apart c. to c. A neat iron fence between the tracks, 4 ft. high, with two rails ⅜ x 1¼ ins. and pickets ½-in. square, 5 ins. apart, with ornamental tips and spacing pieces, made with removable panels, will cost about $1.10 to $1.25 per ft., erected. All fences between tracks should have gates for the use of employees, the gate having a spring lock, which is opened by a button or knob not readily found by the reckless passenger who tries to cross the tracks Two designs of iron fence used in railway service are shown in Fig. 81, the list prices of which are about $2.88 and $4.40 per ft., subject to discount, these prices including one coat of paint and all necessary panel

posts, but not the newel posts. For station grounds a fencing of horizontal round or ribbon wire carried in notches in flat, angle or T-iron posts is very generally used, the posts having back and side braces at intervals. The style of fence with woven wire netting, shown in Fig. 77, is used by the Fremont, Elkhorn & Missouri Valley Ry. for the parks which are being made at nearly all the stations. It is as cheap as a board fence, and lasts longer, while loungers cannot sit on it or cut it.

Snow Fences.—The style of fence to be used on any road depends upon the locality and the amount of snow. In prairie country the snow fences are of great importance, as that is the most troublesome country in which

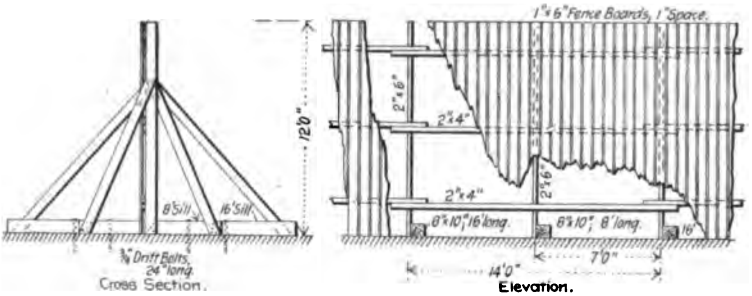


Fig. 82.—Permanent Snow Fence; Canadian Pacific Ry. (Winnipeg Yard.)

to deal with snow, especially if the track is not raised, or raised but little above the normal surface of the country by an embankment. The fences may be either permanent or portable, the latter having pivoted braces, so that they can be folded flat and piled in stacks when not in use. The per-

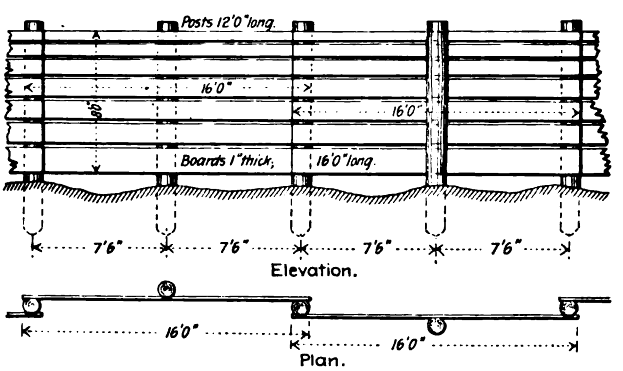


Fig. 83.—Permanent Snow Fence; F., E. & M. V. Ry.

manent fence should be at least 50 ft. from the track, to allow for the slope of the drift, and may be eight or ten boards high. The form shown in Fig. 82 is that used by the Canadian Pacific Ry. at its Winnipeg yards, and for protecting other division yards, etc., while that shown in Fig. 83 is used by the Fremont, Elkhorn & Missouri Valley Ry. The movable fence, shown in Fig. 84, is used by the latter railway, and is a good example of this style of fence; the braces and stakes are pivoted together by carriage bolts, so that when taken up in the spring the panels can be folded flat

and piled on the right of way. On the Minnesota Division of the Northern Pacific Ry., the greater part of the snow fencing is 9 ft. high, posts 8 ft. apart, with 8 boards 1 × 6 ins., and 6 ins. apart. There is also a considerable quantity of tight-board fence, 8 ft. to 10 ft. high, which is found to be by far the most effective in heavy snow. The portable snow fence is of the "saw-buck" pattern, with legs 2 × 6 ins., bolted 2 ft. from the top, with a spread on the ground of 5 ft. 8 ins. The boards are spaced as in the permanent fence. This fence is fastened to stakes driven in the ground.

If the movable fence is used as auxiliary to a permanent fence it may be placed 100 ft. beyond the latter, or where required to break the force

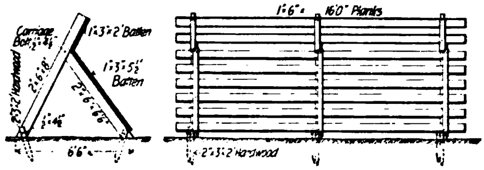


Fig. 84.—Portable Snow Fence; F., E. & M. V. Ry.

of the drifting snow, the eddy formed by the wind causing the snow to be deposited on the track side, as in Fig. 85, while beyond is the secondary drift. When the first drift is as high as the fence the snow will blow over, and the fence may then be placed on top of the drift. If it becomes buried in the snow, a wall may be built of blocks of snow, wide enough for stability and 6 or 8 ft. high. Many western roads prefer this plan to the use of movable fences, employing extra gangs to build the snow

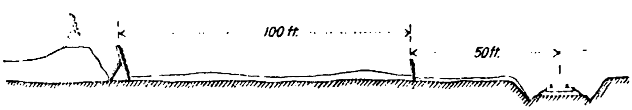


Fig. 85.—Position of Permanent and Portable Snow Fences.

walls, but work of this kind is usually very hard, being carried out during severe cold and often in the face of a high wind and blinding snow. The snow fences should extend beyond the ends of cuts and then flare in gradually towards the track, so as to protect the cut from drifts from winds blowing at an angle to as well as directly across it. If they are not extended far enough, a drift may be formed by a wind blowing obliquely through the cut, and cause a derailment, the engine or snow plow first striking one side of the oblique drift. The Canadian Pacific Ry. finds the best and cheapest snow fence to be made by setting 8-ft. slabs 12 to 18 ins. in the ground, 75 to 100 ft. from the track. The big ends are placed in the trench, touching one another, which leaves the fence a little open at the top. The cost is about $4 per 100 ft., it is easily moved, and there is no trouble from its being blown down. This road also follows an excellent plan in widening out cuts to give very flat slopes, using the material excavated to form permanent snow banks or fences a little distance from the edges of the cuts. Rows of small balsam, cedar or other small evergreen trees,

8 ft. apart, staggered in two rows, the nearest row being 100 ft. from the track, make good snow fences or snow breaks, but their use is not generally practicable.

Cattleguards.

Where highways are crossed at grade, a cattleguard is usually placed across the track at each side of the road, to prevent cattle from straying onto the track or right of way. They are also used to some extent at the approaches to bridges, tunnels or deep cuts. On the Cincinnati Southern Ry. the cattleguard is placed some distance from the bridge and the fence is carried along on each side to the abutments or under the first span. At tunnels the cattleguard is placed near the mouth of the approach cutting, and the fence is carried along the cut and over the portal. For deep and narrow cuts the cattleguard is placed near the mouth of the cut and connected by wing fences with the main fences extending along the right of way, parallel with the cut.

It is not as easy to turn cattle as might be supposed, and very generally they will become accustomed to the guards and find a way to cross them. If straying along the road they will sometimes spend considerable time in trying the guards, either from a desire to wander or to reach a tempting patch of grass or hay. Hungry cattle are especially venturesome. Some cattle are inveterate wanderers, and will cross almost any form of guard, even as others are inveterate fence breakers or jumpers. If being driven they will often either run blindly into or over the guard, and the length of the guard should be sufficient to deter them from jumping. Hogs and sheep are difficult to stop, and are very persistent in their attempts to reach forbidden ground. If cattle are standing up when struck by a train there is a good probability of their being thrown clear of the track, but if they are lying down a derailment is almost inevitable. The killing of cattle is a troublesome feature, especially in the west, where so much land is unfenced, both on account of the liability of injury to trains and passengers, and the amounts involved in paying for cattle (the value of the animals being usually put at a maximum). It does not seem reasonable, however, to hold the railway company alone responsible for the killing of cattle, as is usually the case, and not to hold the owner responsible for not fencing his land or for allowing his cattle to stray in such a way as to endanger the safety and lives of railway passengers. The trains have a right on the track, but trespassers and cattle have no right, and this should be recognized.

Pit Cattleguards.—The cattleguard should be considered as a part of the fence, and not a part of the track, and this distinction puts the pit cattleguard out of the question. Cattleguards may be divided into two general types: pit and surface, the latter of which is now most generally used. The pit guard consists of an excavation in the roadbed, the full width between wing fences, or about 12 ft. wide in the clear, 5 to 6 ft. long (lengthwise of the track), and 30 to 36 ins. deep below base of rail. The pit is often entirely walled up with timber or masonry, but the ends should be left open to provide for drainage. The rails are carried across the pit upon stringers, or upon crossties laid upon the stringers. In the latter case, shown in Fig. 86, the edges of the ties should be beveled off (except at the rail seats) for about 4 ins. in depth of a tie 6 ins. thick, so as to afford but an insecure footing to cattle attempting to cross. This has the objection of being liable to cause the animal to slip through while trying the guard, so

that it could not escape and would probably cause the wreck of the train. In case of a derailed wheel or truck reaching the guard the beveled ties would afford little greater security than the open pit. Another plan, also shown in Fig. 86, has ordinary ties laid on the stringers, and a series of longitudinal beveled wooden slats nailed upon them,parallel with the rails. The pit guard, however, has many disadvantages and objections, and it is as dangerous a structure as the open culvert, which latter structure railways are rapidly eliminating. In case of a derailed wheel or truck the pit is almost certain to cause a wreck, while cattle are very liable to fall into a pit whether entirely open or crossed by beveled ties. The pit also makes

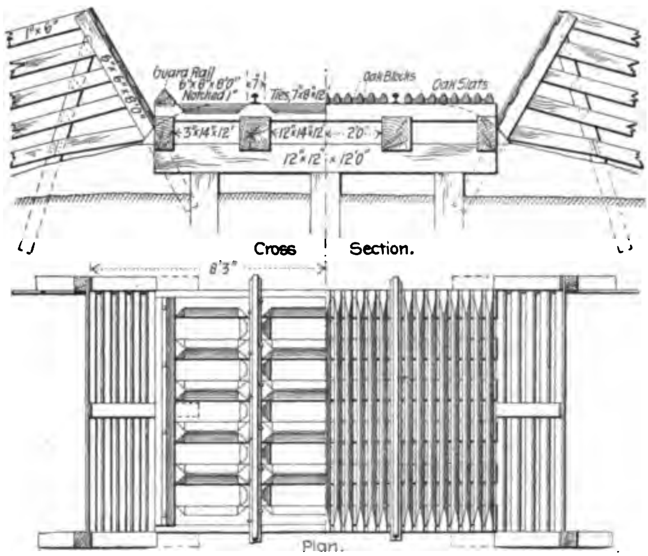


Fig. 86.—Pit Cattleguard.

a bad riding place in the track, by breaking up the continuity of the roadbed, and in case of track heaving on either side the blocking or shimming of the rail on the stringers is not easily done so as to make a good piece of work. As the pit is below subgrade, the frost is likely also to heave the side walls. The timbers are also likely to catch fire, to rot, or to settle; and the pit forms a receptacle for dirt, refuse and moisture.

Surface Cattleguards.—These are rapidly supplanting the old pit guard, since they are free from danger to trains, and (if properly constructed) are as efficient or even more efficient in turning cattle. The simplest form consists of wooden slats 5 to 8 ft. long, and of triangular section, made from 3½ or 4-in. pine sticks cut diagonally, nailed to the ties, but these are generally seen only on branches and small country lines, and are, as a rule, in poor condition, with slats split, broken off or ripped up. A better plan is to have slats and spacing blocks bolted together in sections. One or two of such sections are placed between the rails, and two are placed outside the rails. Other sections are placed in the space between the tracks on a double track line, being nailed to three or four ties placed between the tracks. The construction is similar to that covering the left hand side of the pit cattle-

guard, Fig. 86, the slats being about 10 ft. long, 4 ins. deep, ½-in. wide on top, and 2 ins. on the bottom, the lower 2 ins. of the sides being vertical, so as to fit the spacing blocks, 2 x 2 ins., and 8 ins. long, placed between the slats at the ends and middle. The parts are held together by three ⅝-in. rods passing through the slats and spacing blocks. In some cases a strip of barbed or twisted wire is nailed along the tops of the slats, but these are liable to get loose and make a very poor looking guard. The Louisville &

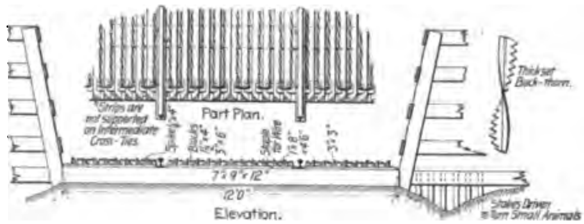


Fig. 87.—Wooden Surface Cattleguard; Louisville & Nashville Ry.

Nashville Ry. uses a surface cattleguard of the pattern shown in Fig. 87, having triangular wooden slats 3 x 3 ins. on the right angled sides, 8 ft. 6 ins. long, laid with the inclined faces towards the rail, the middle slat having a 6-in. base and both sides sloping. The slats are nailed at the middle and each end to a plank 1 x 8 ins., those between the rails being 4 ft. 6 ins. long, and those outside the rails 3 ft. 3 ins. long. The slats are

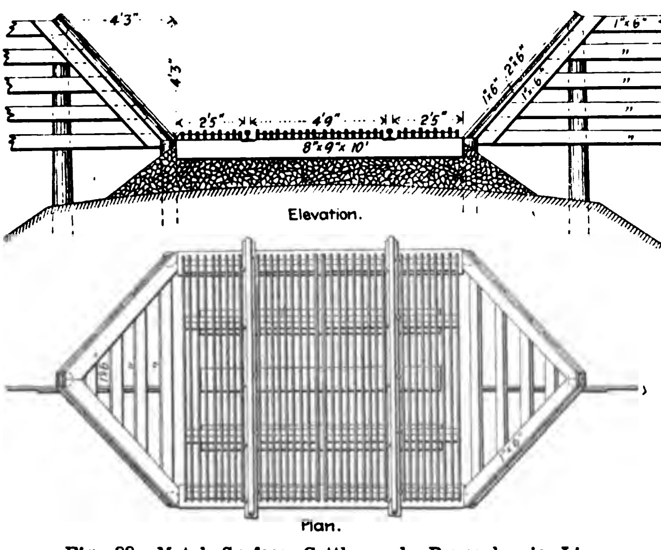


Fig. 88.—Metal Surface Cattleguard; Pennsylvania Lines.

separated by spacing blocks 1½ x 4 ins., nailed to the planks, and strips of twisted ragged edge ribbon wire (thickset buckthorn wire) are laid between the slats, with the ends stapled to the spacing blocks. The cross planks are spiked to three ties, 7 x 9 ins., 12 ft. long, laid between the track ties, so that the guard is entirely independent of the track. The ballast is dug out between the ties.

Among the various designs for surface guards are some in which the animals are compelled to step on planks between the ties, which planks are loose, and are connected to a transverse rod carrying several prongs 18 to 24 ins. long, forming a fence which rises in front of the animal, but lies normally flat on the ties. A simpler plan consists of four or five rows of 10-in. drain tiles placed on end between the ties, the latter being capped by timbers of triangular section. The tiles are about 18 ins. long, placed on a bed of gravel 3 or 4 ins. thick to provide drainage, and have their tops level with or a little above the rail head. Snow can be removed with a scoop, and renewals are easily effected. This has been used on some western roads and has been found simple, effective and cheap. With tiles costing 15 cts. each at the works, the cost will be $6 for four rows of ten tiles (four between the rails), exclusive of transportation and laying.

Metal surface guards are now being very generally adopted as they are efficient, economical, permanent, and do not interfere with the track work. The majority of these consist of a series of iron slats or rods parallel with the rails, and arranged to form but an insecure footing. One of these, used on the Pennsylvania Ry. Lines West of Pittsburg, is shown in Fig. 88. The slats are supported in triangular iron cross-pieces, and are set alternately high and low. In some cases flat bars set on edge are used, having wavy or saw-tooth top edges, and sometimes barbs on the sides, so as to cause pain to any animal making a determined effort to cross. While the barbs add to the effectiveness of the guard in turning hogs and small stock, they are open to the objection of possibly causing injury to stock, for which the railway company may be held liable. One make of guard has a sort of web or mattress of woven wire covering the track, but it would seem that animals might get their legs through and be unable to get off the track. Metal guards which have a bottom plate covering the ties and ballast have disadvantages over the slat forms in interfering with tamping and track work, and being liable to cause rotting of the ties by holding water between the plate and tie, while the heat of the plate in summer also aids in this effect. A guard used on the Houston & Texas Central Ry. has iron or steel sheets pressed or rolled to form triangular ridges 8 ins. wide, separated by 3-in. flat pieces which come over the spaces between the ties, the ridges being parallel with the ties. The height of the ridges is equal to that of the rails. Three pieces are used, the middle one 48 ins. wide, and the outer ones 22 ins. wide. The Sheffield guard is a flat plate with rows of triangular teeth stamped out of it, the teeth being about 3 ins. high, staggered, with these of alternate rows sloping slightly in opposite directions. Four plates are used, two between the rails and one outside each rail.

Some of the principal makes of metal surface guards are shown in Fig. 89. The Kalamazoo guard has triangular ridges, and triangular teeth punched up out of the flat strips of plate between the ridges, so that an animal's hoof will slip down upon the teeth; the ridges are higher than the teeth, so that a person falling on the guard would not be likely to be badly hurt. This guard, 9 ft. long, weighs about 375 lbs. The National guard has slats of T or Λ section attached to cross pieces, alternate slats being 1½ ins. above the others. A guard 9 ft. long and 10 ft. wide across the track, weighs about 400 lbs. Another form of the National guard has flat plates, 2½ and 3½ ins. high, 2¾ ins. apart, set on edge in the transverse pieces; this weighs 560 lbs., or 140 lbs. for each of the four sections. The

tops of the plates may have saw teeth pointing towards the highway, and where small stock are to be dealt with the plates may have barbs punched out of the sides and pointing diagonally upward; this latter plan has been specially designed for the southern "razor-back" hog, who usually surmounts any cattleguard. The Merrill-Stevens guard has slats of T-iron, about $1\frac{1}{4} \times 1\frac{1}{4}$ ins., parallel with the rails, set diagonally in the end cross pieces, and made level with the rail head; the space beneath the guard

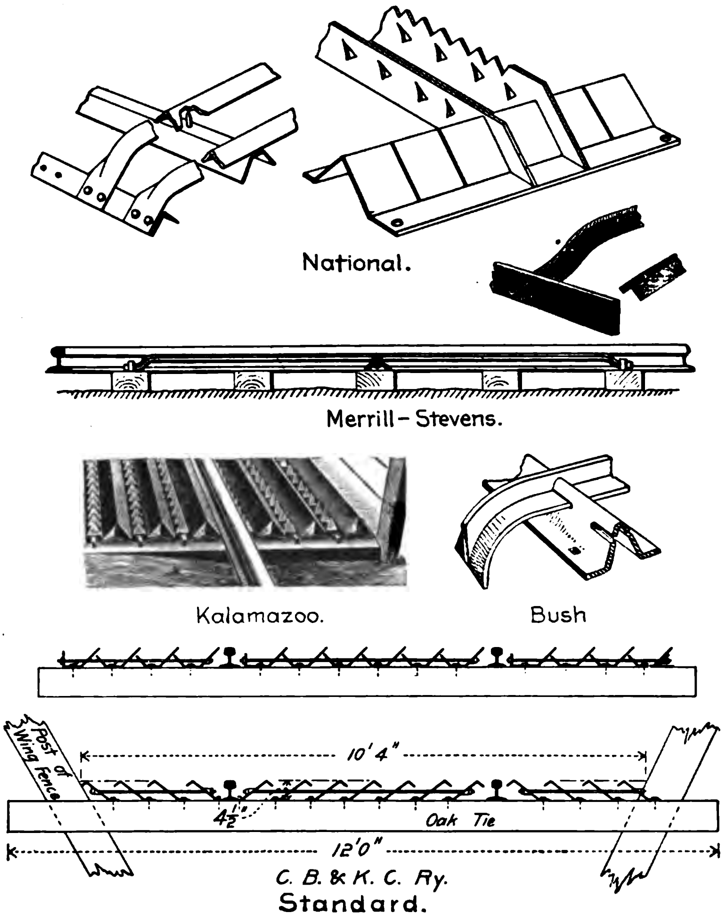


Fig. 89.—Metal Cattleguards.

and the insecure footing of the slanting bars tend to check cattle from attempting to cross. The Standard guard has slats of flat or Z-shaped plates, parallel with the rail and set to incline towards the rails, the lower edge of each plate being bent to form a supporting ridge for the adjacent slat. The Bush guard has slats of inverted T-irons, 2 ins. apart, carried in slotted cross-pieces of pressed steel, the bars being at different heights; this guard is made in four interchangeable sections and weighs about 450

lbs. The metal cattleguards are more expensive than the others in first cost ($15 to $20 each), but they are more durable, require little attention, and are independent of the track construction.

Wing Fences.—To shut off the right of way between the track and the boundary fence, a board or wire wing fence is built opposite the middle or end of the cattleguard, and should have the end post inclined away from the track, so as not to be struck by persons on car steps or freight car ladders The clear width between wing fence posts at rail level should be 10 ft. to 12 ft. on single track. Sometimes the wing fences alone are used, but the more general practice is to put a rectangular or triangular panel of apron fence on each end post, parallel with the track, as shown in Figs. 86 and 88. The Louisville & Nashville Ry. cattleguard, Fig. 87, has the end posts of the wing fences in line with the 12 ft. ties carrying the guard, and the apron fence has a rectangular panel 9 ft. long. The ditch is closed against small animals by stakes driven into the ground and nailed to the bottom of the wing fence. The wing fences and aprons should be kept in good repair and well whitewashed, as cattle object to passing a whitewashed fence more than an ordinary fence.

CHAPTER 9.—BRIDGE FLOORS AND GRADE CROSSINGS.

While solid floors for steel bridges are coming into more general use, the most common form is still the open floor, consisting of timber stringers resting on the floor beams and carrying sawed track ties. In rare cases the rails are laid on longitudinal timbers, as on the Long Bridge of the Pennsylvania Ry., at Washington, D. C., and the Victoria Bridge of the Grand Trunk Ry., at Montreal. In designing the floor system of a bridge or trestle, the emergency of derailed trains must be considered and provided for, and a floor in which such provision is made need cost but little more than one in which timber is skimped, while it may save many lives and several thousand dollars in case of a derailment. Thus the slight construction of the floor on the iron deck truss bridge of the Grand Trunk Ry., at St. George, Ont., caused the wreck of a derailed train in 1889, with a loss of 13 lives and about $200,000, while it was estimated that for $520 a floor could have been built which would have carried the train. This floor had ties at least 8 ins. apart in the clear, with guard rails on the ends of the ties only, so that the wheels easily "bunched" the ties, leaving wide gaps into which the wheels dropped. Bridge ties should be not more than 4 ins. apart, and kept from "bunching" by having the guard timbers boxed out over each tie, or by having spacing blocks between the ties, while every tie or every other tie should be secured to the stringers by drift bolts or screw bolts. Sawed ties of oak or yellow pine (which latter is less liable to warp) are commonly used, and are 7×8 to 8×8 ins. as a rule. For single track, the length may be 8 ft. 6 ins. to 11 ft., while on double track sawed timbers, 8×8 ins., 24 ft. long, may be used. On iron structures there is often trouble from corrosion due to the drippings of brine from refrigerator cars. To prevent this, planks, 1×6 ins., may be nailed to the under sides of the ties, closing the spaces between them, a strip 1×2 ins. (or the width of the tie spacing) being nailed to the upper side of the

plank. The bottom of the troughs thus formed may be filled in with tar, smoothed off, and an eaves trough laid along one side of the ties to catch the brine, which is conducted below the iron work by drain pipes.

Solid floors for metal bridges have the advantage of enabling the standard track to be carried across the bridge, while the dead load of the floor and ballast not only requires a heavier construction of bridge, but the ballasted floor absorbs much of the vibration which is so detrimental to the structure. As a rule the floors are of transverse troughs of rectangular or trapezoidal section, filled with ballast. Some roads consider that the use of ballast tends to corrosion of the floor, and prefer to use deep ties resting in the trough, but experience has shown that this objection is not of such importance as has been supposed. The troughs should be closely and securely riveted to the girders by means of continuous angle irons above and below; and not merely secured to brackets, leaving open spaces between the troughs and the girders. On the solid floor of the New York Central Ry. viaduct in Park Ave., New York city, the 100-lb. rails are bolted directly to the transverse troughs, steel tie-plates being inserted between the rail and trough. As a track circuit is used for signal operations, it is necessary to provide some efficient means for insulating the rail from its metal supports. For this purpose there are three pieces of insulated fiber. One forms a bed plate, and has slots for the vertical edges of the two shorter pieces of angle section which fit between the edge and top of the rail flange and the bolted clamps by which the rail is secured to the metal structure.

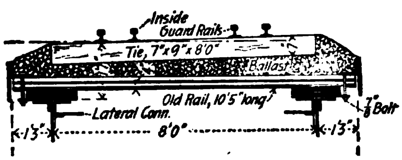


Fig. 90.—Bridge Floor of Old Rails; C. & O. Ry.

The same device may be applied to wooden ties when desired, substituting two screw spikes for the bolts in the clamps. On some of the street crossings of the Illinois Central Ry., in Chicago, the floor is of transverse rolled troughs, 6 ins. deep, 16 ins. c. to c., no ballast being used. A longitudinal timber, 4×8 ins., is laid under each rail, the rails being secured by bolted clamps. The bolts are slightly inclined, and pass through wooden insulating blocks ½-in. thick, under the stringer, the nuts being under these blocks. The insulation is made necessary by the use of track circuits for the automatic block signals. The fastenings are placed at intervals of 16 ins. On each side of each stringer is a deck beam or bulb iron, 20 ins. high and 8 ins. wide, placed 9 ins. apart, c. to c., the lower edges of the stringers being notched to rest on the flanges of the beams. The thunderous reverberating sound caused by trains running on plate girder bridges or viaducts, with or without solid floors, suggests the desirability of using a cushion bed of ballast or some other means to absorb the vibrations which cause the noise. This is especially important on city viaducts.

Floors of old rails are used to some extent, particularly on deck bridges. On the Chesapeake & Ohio Ry. some plate girder deck bridges have old 70-lb. rails, 4 ins. high, spaced 6 ins. c. to c., this spacing enabling the rail bases to come between the rivet heads on the girders, as shown in Fig. 90.

The rails are 10 ft. 5 ins. long for single track (with girders 8 ft. c. to c.), and 23 ft. 5 ins. for double track. They are held down by an angle iron, ½ × 6 × 6 ins., along each end of the floor, this being secured by ⅞-in.-bolts, 12 ins. apart, to the bottom cover plate of the top chord, which is wider than the other cover-plates. The vertical flange of this angle iron is upward and outward, and has a plate ⅜ × 12 ins. to retain the ballast and prevent the rails from shifting laterally. The floor is covered with ballast, 4 ins. deep under the ties, and the spaces between the rails provide for drainage. The floor should be well coated with tar. An angle iron retains the ballast at each end of the bridge, and a plate covers the space between the bridge and the back wall of the abutment. In some cases the floor is of longitudinal troughs, carried on the floor beams. The floor system is also sometimes so formed as to make a trough for each rail, in which any derailed wheels would run, but while this is common in Europe it is very rarely seen here.

Open culverts may often be advantageously replaced by solid banks with masonry arches or iron pipes for the waterway, but where an embankment cannot be used, for lack of sufficient depth, etc., concrete or masonry walls should be built to carry a solid floor of short plate girders (which may be built from scrap at the shops), old rails, or troughs. The floor should be given a good coat of tar before the ballast is laid upon it. The New York Central Ry. uses a single row of old 65-lb. rails (laid closely, side by side) for a clear span of 8 ft., reinforcing this for a span of 10 ft. by four inverted rails between the others under each track rail, or by old 80-lb. rails under the ties. For 12-ft. spans, the 80-lb. rails under the ties may be reinforced by three or four inverted rails under each track rail. These floors are covered with broken stone ballast, about 15 ins. deep, under the ties. For spans of 15 to 30 ft., longitudinal trough floors are used, the troughs being built up, of rectangular section, 12 ins. wide and 16 ins. deep. Rolled troughs may also be used for short spans. On some roads the rail floors are covered with concrete about 12 ins. thick at the middle and 4 ins. at the sides, the ballast being laid upon this. The rails should be held together by tie rods at the ends. For crossing irrigation ditches, the Southern Pacific Ry. uses two 12-in. channel irons under each rail, the channels being placed back to back, with riveted channel iron bearing pieces or saddles between. The saddles carry creosoted blocks, 4 × 12 ins., 12 ins. long, and the rails are bolted through these to the saddles. The channels weigh 30 and 50 lbs. per ft. for spans of 12 and 15 ft., and their ends rest on shoes on 12 × 12-in. cap sills. It would be much better to use wooden stringers instead of wooden blocks, so as to give a continuous bearing for derailed wheels. Solid floors are specially desirable for short span bridges and for carrying fast trains, as they afford many advantages in safety, permanence, and smooth riding. The first cost is, of course, considerably greater, but there is a decided saving in the maintenance work, while the track maintenance can be attended to by the regular section gang, instead of by a special gang of bridge carpenters.

A plan adopted on the Richmond, Fredericksburg & Potomac Ry. to protect the floors of trestles and culverts from fire is to fasten boards, 2 or 3 ins. thick and 6 ins. wide, under the ties, closing the spaces between them, while similar boards are placed along the ends of the ties, forming troughs which are filled with gravel. The durability of the stringers is not affected, and the arrangement is considered preferable to the open floor.

Ballasted culverts, Fig. 91, are used on the Southern Pacific Ry. Four piles at each end carry caps, 12 × 12 ins., 12 ft. long, upon which is a close floor of longitudinal timbers, 10 × 10 ins. and 16 ft. long, with a coping timber 4 × 6 ins., fastened to each of the outer floor timbers. Ballast is filled in to a depth of 9 ins. under the ties, and the face of the bank is held up by planks behind the piles. For culverts having two bents the caps are 13 ft. long, with 13 instead of 12 floor timbers. The Illinois Central Ry. uses a similar floor for trestles, with 14 cypress timbers 10 × 12 ins., the two outer timbers having similar timbers bolted on top for copings, using ¾-in. bolts, 42½ ins. long, at the caps and midway between the caps. Planks 2 × 6 ins., 11 ft. 8 ins. long, are spiked to the underside of the floor timbers by ⅝-in. boat spikes, 6 ins. long. The timbers are black and red cypress, not creosoted, and last about 12 years in the low swampy country of the South. A somewhat similar plan for trestles on the Houston & Texas Central Ry. has eight stringers, 7 × 14 ins., 28 ft. long, 12 ins. apart, carry-

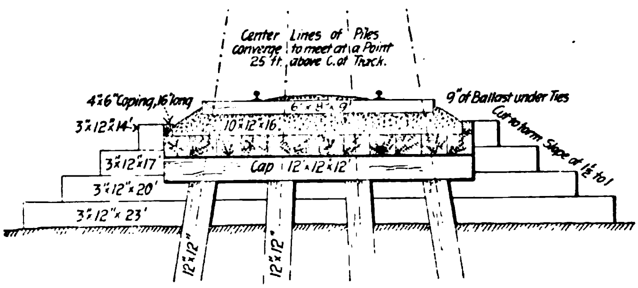


Fig. 91.—Ballasted Culvert; Southern Pacific Ry.

ing a floor of transverse planks, 2 × 6 ins., 14 ft. long, with a timber 4 × 6 ins., 28 ft. long, bolted along each side to retain the ballast, which is filled in 10 ins. deep under the ties, and filled in over the ties at the middle. All the timber is creosoted, and the trestle cost $8.50 per lin. ft., the extra cost per floor being about $1 per ft. By this arrangement individual stringers can be renewed more easily than where there is a close floor of stringers. These solid floors have the following advantages: 1. Safety from fire; 2, Low cost of maintenance, as practically no repairs are required, and the lining and surfacing can be done by the section gangs instead of by the bridge gangs; 3. They give an easy riding track, and in case of derailment there is less liability of damage to the structure.

On some of the long high trestles of the Canadian Pacific Ry. which are not likely to be renewed for some years, and which are so located as to make reconstruction difficult in case of their destruction by fire, the floor is to be protected from cinders by laying planks across the ties and filling in gravel or cinders to a depth of 2½ or 3 ins. This is a very simple and cheap plan, not interfering with the construction or repair of the trestle, and should be very effective.

Bridge Guard Rails.

As a general thing there are wooden guard rails about 6 × 8 ins., 8 × 8 ins., or 10 × 10 ins., placed outside the track and 10 to 18 ins. from the gage side of the rail head. These timbers should be boxed out ¾-in. to 1½ ins. for the ties, and bolted to every third tie by a ¾-in. bolt passing through

guard, tie and stringer. They are more effective if faced with an angle iron on the top corner. Beyond the ends of the bridge the guard timbers should flare out for 50 or 60 ft. on the approaches, so as to catch any wandering derailed wheels and guide them onto the bridge, and in some cases strong snubbing posts set deep in the ground are placed in line with the bridge trusses, so that the truck of a derailed car so far off the track as to strike the truss would be stripped from the car body before reaching the structure. These posts may be of three piles in a cluster, or a 16 x 16 in. timber, 12 ft. long, with 4 ft. above ground. On wide bridges with long ties, extra guard timbers are sometimes placed near the ends of the ties, but should not be used as substitutes for the regular guard timbers, which latter should be close to the rails. In some cases also there are inside guard timbers, with an angle iron on the top corner or laid on the ties and bolted through the guard timber, the latter plan forming a path for derailed wheels.

Iron guard rails placed between the track rails are very commonly used, either with or without the outer guard timbers, but it is better to use both. They are of new or old rails, well spiked and spliced, spaced 7 to 12 ins. clear from the track rails, and extended 150 ft. or more on the approach,

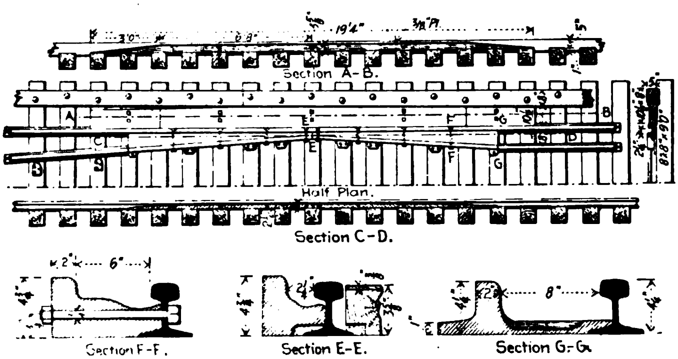


Fig. 92.—Rerailing Device at Bridges; S., F. & W. Ry.

being gradually brought together and connected to an old frog point or special point, beveled so as not to catch loose chains or brakebeams. The possibility of a car being so far off the track that its nearer wheels will take the wrong side of the guard rails may be provided for by placing special guard timbers or guard rails just before the point where the inside iron guard rails are brought together. These rails would be 30 ft. long, 8 or 10 ins. from the track rails opposite the point of inside guard rails and flaring out to a distance of 4 ft. 8½ ins. for the track rails. A piece of rail 15 ft. long should extend from the inner end of each of these guard rails, parallel with and 8 or 10 ins. from the track rails. These outer guard rails should be laid on long ties and supported by rail braces.

The Erie Ry. uses inside guards 7 ins. clear from the track rails, and outside guard timbers 16¾ ins. from the gage side of the track rail. A rerailing device should be placed about 50 to 150 ft. from the bridge, so that if the truck is too far out of line to be saved by this device the car will be wrecked on the bank and not on the structure. One of the best of these is the well-known Latimer rerailing guard, one form of which, as used on the

Savannah, Florida & Western Ry., is shown in Fig. 92. The improved form, known as the Childs-Latimer rerailing device, is made by the Morden Frog & Crossing Co., of Chicago. The Michigan Central Ry. uses three parallel lines of steel rails between the track rails, secured by Bush interlocking bolts, the middle line being bolted through the ties. On some roads the inside guard rail is laid on its sides, with the base facing the track rail. The bridge floor of the New York, New Haven & Hartford Ry., Fig. 93, has ties 11 ft. long for single track and 24 ft. for double track, all 8 × 8 ins., 8 ins. apart (which is too far). The outside guard timbers are 6 × 8 ins., laid flat, and boxed out ¾-in. over the ties, with the inner edge faced by an angle iron ¼ × 2½ × 3 ins. They are 10½ ins. clear from the track rail, and flare out till they are 12 ft. apart, 70 ft. from the bridge, ending 8 ft. beyond the point of the inner guard rails where brought together. The inside iron guard rails are 8 ins. clear from the track rails. Guard timbers should be bolted to every second, third or fourth tie, and if jack stringers are used the guard timbers may be bolted through to both tie and stringer. The bolts should be ¾ or ⅞-in. diameter, with cast iron washers about ¾ × 3½ ins. Every third or fourth tie should be bolted to the stringers.

The outer guards may be 12 to 18 ins. from gage side of rail, or 7 to 9 ft. apart; and the inner guards 7 to 12 ins. from the track rails, or, wide enough to allow derailed wheels to run between the guard and track rails. The sooner a derailed wheel is met and guided the better, and with guard timbers more than 8 ft. apart the wheels have a chance to turn or slue to a greater angle and be thus more likely to break or move the guard or to

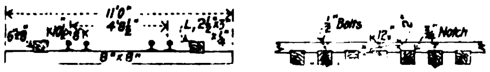


Fig. 93.—Bridge Guard Rails; N. Y., N. H. & H. Ry.

climb over it. The purpose of a wider spacing is claimed to be to provide for trucks very far off the track, but these should be provided for by flaring the timbers out on the approach and using rerailing guards, the track being filled in and well tamped with ballast for the full width between the flaring timbers. In some cases the outside guards act merely as tie spacers, being so far apart that a derailed car would strike the bridge truss before the wheels encountered the guard timbers. Inside guard rails are less likely to be jumped, as the back of the wheel bears against the rail and not the sharp edge of the flange. To avoid the use of heavy guard timbers, it has been proposed to lay each rail in an iron trough, or a channel iron, about 15 ins. wide, or wide enough to leave about 6 ins. clear between each side of the rail head and the side of the channel.

Trestles should have a similarly strong and safe construction of floor, with guards and other safety appliances; and the same applies to all openings, such as culverts and waterways, though open floors should be avoided as far as possible for such small structures. Each one of these openings is a source of danger, but the small ones too often have short ties, widely spaced, and small useless guard timbers along the ends of the ties. Trestles with long ties may have jack stringers under the outer guard rails to prevent the ties from being tilted up by a derailed truck. On long trestles

or deck bridges there should be a plank footwalk along one side or between the tracks, or else refuge places should be placed at intervals.

Elevated Railways.

The track of elevated railways resembles that on bridges in general, except that it has usually four heavy guard timbers, one on each side of each rail, secured to the ties by wooden pins, 10-in. lag screws or iron bolts, the nuts of the latter being generally in cup-shaped washers let into the wood. These timbers are frequently faced with angle iron on the top inner corners, and are heavily reinforced by additional timbers at curves, while the inside timber is replaced by an iron guard rail for the low rail on sharp curves. The New York elevated railways have 90-lb. rails, with suspended or bridge joints, and have 20 ties per rail, with tie-plates on each tie. The track of the Chicago & South Side Elevated Ry., Fig. 94, is a good rep-

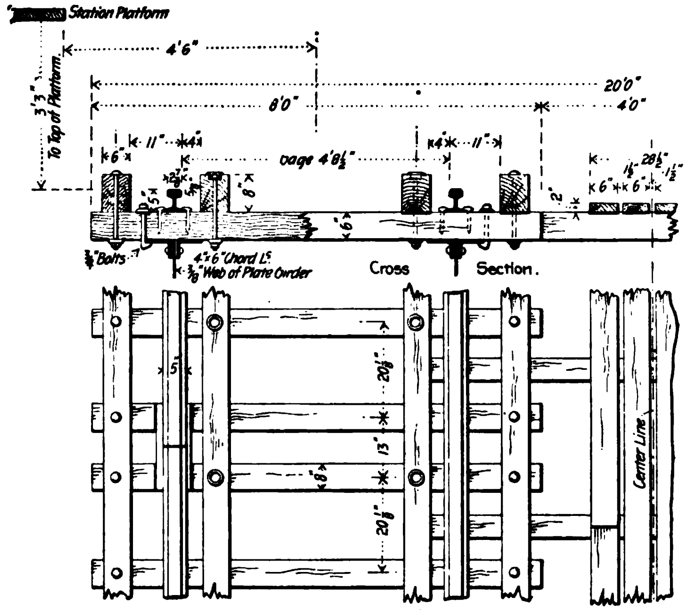


Fig. 94.—Track Construction of the Chicago & South Side Elevated Ry.

resentative of this class of track. It consists of 90-lb. rails, secured by spikes 9-16 x 5½ ins. to hardwood ties 6 x 8 ins., 8 ft. long, spaced 20 ins., c. to c. The ties are fastened to the top chords of the girders by hook bolts. The two guard timbers for each rail are 6 ins. wide and 8 ins. high, the inner one being 4¼ ins. from the rail, and the outer one on the ends of the ties, though it is more common to have them both close to the rail, with a clearance of 4 ins. and 9 ins. from the gage side of the rail. Extending between the tracks, or in some places on the outer side of the tracks, are timbers 6 x 6 ins. upon which are laid four lines of plank, 2 x 6 ins., forming a walk for the track men and employees. The outer walks are usually provided with a railing of cast-iron standards and gas pipe hand rails. In some cases, as on the elevated railways at Kansas City and Hoboken, ties are dispensed with, and each line of rail rests on wooden blocks on saddles riveted between a pair of iron stringers or girders, placed close together

and acting as guard rails. The Kansas City line has 48-ft. pin-connected trusses, with top chords composed of two 10-in. channels, 8 ins. apart, with bent steel plates riveted between their webs at intervals of 16 ins. On each plate is an oak block 1½ ins. thick, upon which the rail rests, the upper parts of the channels forming the guard rails. These methods give less obstruction to light, which is an advantage where the roads are built along city streets. It has been proposed to dispense with ties altogether, laying the rails on longitudinal timbers on the top chords of the girders, with felt packing to reduce noise.

Road and Street Crossings.

The avoidance of grade crossings has rarely been a consideration in railway location in this country, and it is worthy of note that in the St. Louis extension of the St. Louis, Keokuk & Northwestern Ry., built in 1894, the grade line was laid out on the profile so as to avoid crossings at grade wherever possible, some of the roads having their grades slightly changed on condition that the railway company would macadamize the roads. Inexpensive timber or plate girder bridges were used. In too many cases railways still run through towns and cities on the street grade, generally having their own right of way and merely crossing the streets, but sometimes running along the middle of a street, and in such cases it is very difficult to keep the track in good condition. In many cities steps have been taken to eliminate the grade crossings, the railway being either depressed and laid in an open cut with retaining walls, and crossed by bridges; or raised on a viaduct or bank and crossing the streets by bridges. Street grades are very frequently changed at the same time so as not to require the tracks to be raised higher than necessary. Such work is often very difficult and almost invariably very expensive, involving a large amount of railway and municipal work, and the execution of the work during traffic, which is an unfavorable condition for economy.

Where the tracks run along or across city streets, an iron guard rail is generally placed inside the track rail, and the paving filled in over the ties, leaving only a flangeway, which should have a filling piece up to the level of the underside of the rail heads. In some cases a line of planking is laid along the outside of the rail head. A neat and substantial arrangement is used by the New York Central Ry. through paved streets. The ties are placed 4 ins. deeper than usual, laid upon 6 ins. of gravel ballast, with 6 ins. of concrete between the ties and extending to the sides of the street. Upon each tie are spiked two iron chairs 4 ins. high, with a base of 10¼ × 4¼ ins., and weighing 21 to 28 lbs. each, for intermediate and joint chairs. Upon these are laid the track rails, secured by steel spring clamps of approximately semicircular form, which are driven on parallel with the rail, gripping the rail flange and top of chair. The chair brings the top of the rail to the level of the paving blocks. To the inside of the web of each rail is bolted a continuous angle bar of special section with a broad flange at the top, the built-up section resembling a side-bearing street-rail, the depth of flange being the full depth of the rail head, or 1 9-32 ins. for an 80-lb. rail. The bolts are at intervals of 4 ft. 4½ ins., and at the rail joints only an outer six-bolt splice bar is required, the clamps on the three joint chairs gripping the flange of this bar. The track and special rails break joint about 18 ins. Over the concrete and ties is a 2-in. layer of fine sand, upon which are set the paving blocks, those outside the rail being level

with the top of the rail and those inside the rail level with the top of the angle bar. The cost is about $13,500 per mile of single track, laid and ballasted, but exclusive of concrete and paving, which are the city's work.

Country road crossings are either planked all the way across or have planks against the rails, and gravel or cinder filling between. The planks are usually 3 × 8 ins., or 4 × 12 ins., and from 8 to 12 or 16 ft. long, the former being for farm crossings and side roads. Five planks 10 ins. wide will fill in neatly between the rails, while two others will be laid outside, one against each rail. With narrow crossings the planks should, as far as possible, be placed so as not to cover up any of the splice bars. If the rails are high the planks rest on strips nailed to the ties, of such thickness as to bring the top of the planking flush with the top of the rail or about ½-in. below it. The ends of the planks are adzed down to a slope for about 6 to 12 ins., so as not to catch loose hanging rods or chains or low brakebeams. Spruce planks are often used, but are too soft, and pine is much more suitable, even more so than oak as the latter is liable to warp. The planks should be spiked by ⅝-in. boat spikes 7 or 8 ins. long, as track spikes are too short to get a good hold in the ties and are more expensive. The outer planks are butted against the rail heads, but the inner ones next the rail must leave flangeways about 2½ ins. wide. These planks may be set back that distance, or their edges may be cut away so

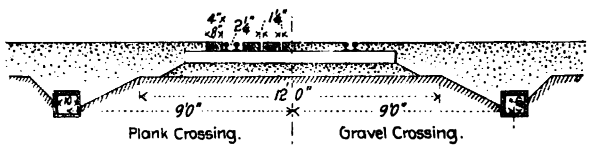


Fig. 95.—Road Crossings.

as to fit under the rail head, leaving flangeways 2½ ins. wide and the full depth of the rail head. A shallow flangeway has the objection of being more easily obstructed by stones, etc., but if the space is left open for the full depth of the rail horses are liable to get the calks of their shoes caught under the rail heads. It is best, therefore, to put in a filler under the rail heads. Two plans of road crossings are shown in Fig. 95.

Where there is heavy traffic a steel rail is frequently placed as a guard rail to form the flangeway and protect the edges of the planking. If placed upright, or laid on its side with the base towards the track rail, a wooden filler piece should be placed in the lower part of the flangeway, as already noted, and if the rail is laid on its side, with the base of the flange towards the track rail, a plank must be cut to shape to rest upon it, this plank being secured by long spikes driven through the plank and through holes in the rail web into the ties. Another plan favored by some roads using iron guard rails at crossings is to place the rail (sometimes lighter than the track rail) on its side, resting on a layer of gravel and having its head against the web of the track rail. If necessary the guard rail may be secured by horizontal bolts. The ends of iron guard rails should be flared out for about 6 or 8 ins. to a width of 4 ins. from the track rail, the end space being filled with gravel, blocking or some form of footguard. If the planking is only laid against the rails, cross timbers may be laid between the ends of the planks, forming a shallow box to be filled with ballast and a top dressing of gravel or cinders. A

similar plan may be followed where iron guard rails are used. If the track is liable to heave, the planks may be removed from farm and unimportant crossings in the winter, so that they may not be struck by engine pilots or snow plows.

The approaches to the crossing should be properly built and graded, and may be carried across the roadway ditches by planks spiked to timbers or old ties, resting on the bank and the roadbed, but these timbers are liable to rot and easily become loose, making an unsightly crossing. It is generally better to carry the ditch through by a box drain about 8 x 10 ins., or an iron pipe 8 to 12 ins. diameter, and then to fill in the earth to make a properly graded approach. Clay pipe is likely to be broken or displaced unless the earth cover over it is pretty thick, while a wooden box drain is likely to break or decay and allow the earth to fall in and block the drain. The ends of the pipe or drain may have screens, and the ends of the pipe may be laid in small dry walls. These pipes should be of ample capacity, and should be cleaned out occasionally. Crossings should always be kept in good repair, not only on account of the safety of railway and highway traffic, but also because defective and unsightly crossings are a frequent cause of public complaint, leading to an ill-feeling against the railway.

Road Crossing Signals and Gates.—Country road crossings are generally protected only by warning signs and cattleguards, though flagmen are employed in some cases, and gates and automatic bell or gong signals are also sometimes used. For suburban crossings of busy lines, signs and gates are very generally used (or flagmen instead of gatemen), and are often supplemented by automatic gong signals, having either a large gong to warn persons approaching the railway, or a small gong to warn the watchman to flag the highway traffic or to close the gates. These audible signals are of two classes; in one the train puts in motion a force which will ring the gong for a certain time, and in the other the train closes an electric circuit, so that the gong continues to ring until the train has passed the crossing. The trouble with many such appliances has been their liability to fail at certain times, which is especially dangerous in cases where this is the only signal, as persons who have once found it inoperative are likely to disregard it entirely in future. As an auxiliary to the gateman, however, the automatic audible signal is very valuable. In this connection it is pertinent to call attention to the folly of employing cheap and incompetent men as flagmen or gatemen at crossings. Such men will not and do not attend faithfully to their duties, and many accidents have resulted from the carelessness of such watchmen.

In most of these signaling devices the apparatus is set in operation by some sort of track instrument, which is struck by the wheels, but in that of the American Signal Co., of Baltimore, which is in somewhat extensive use, it is operated from an electric circuit controller, placed on a telegraph pole, the controller being free from the shocks and vibrations to which a track instrument is subjected. Two opposite rail lengths are insulated, and wires from the two rails of the insulated section and the adjoining uninsulated rails are led to the box containing the controller and battery, while live wires from the controller lead to the gong apparatus at the crossing, the current for which is supplied by a second and smaller battery. In the crossing signal or alarm manufactured by the Pennsylvania Steel Co., of Steelton, Pa., a Siemen's armature (made of an iron spool wound lengthwise with copper wire) is arranged to revolve in the magnetic field

of permanent horseshoe magnets, each revolution producing two impulses of electricity of opposite polarity, or alternating currents. The revolutions of the armature are produced by a fly-wheel train of gearing, which is operated by the recoil of powerful springs, these springs being compressed by the action of a hinged lever placed alongside the rail and depressed by every passing wheel. There is no battery, and the entire plant is out of operation except during the passage of the train and during the revolution of the fly-wheel by its momentum. The mechanism is placed in a box beside the track, 1,200 to 2,000 ft. in advance of the crossing.

Street crossings at yards and stations, where trains and switch engines are constantly moving to and fro, are often protected only by flagmen, who signal the drivers of vehicles when to cross. If there are many tracks an open refuge place should be provided near the middle, so that teams need not wait until the entire crossing is clear. Such crossings, however, are extremely dangerous, especially in dark and stormy weather, when the drivers cannot see the flagman distinctly, and the flagman's view is obstructed by smoke and steam. Ordinary street crossings have usually gates, operated by gatemen or watchmen. In a few cases "portcullis" gates are used, sliding vertically in high frames, but the most common form of crossing gate is a light wooden arm, swinging vertically, and pivoted on a post near the curb, the arm being operated by gearing by means of a crank handle on the post. The arms or gates on both sides of the track are worked together, the connections being usually rods, or chains led through pipes underground. The arms are counterbalanced by iron weights, and may be fitted with targets and lamps. They are sometimes as much as 55 ft. long, with sidewalk arms 35 ft. long, where the tracks cross the street at an angle, but for wide streets it is common to use two arms on each side of the track. The sidewalk arms are operated by segmental racks on the heel of the street arm and sidewalk arm. The gateman usually has a small cabin at the side of the track, but in some cases he occupies an elevated cabin at the side of or between the tracks.

Several roads are now using gates of the above pattern, operated from the cabin by compressed air, supplied by a hand pump. The Pneumatic Gate Co.'s gate is operated by one or two strokes of the air pump lever for each movement of the gate, and the operating cylinder and mechanism are enclosed in the iron posts, these posts being connected by ¼-in. pipes. A pressure of only 7 lbs. per sq. in. is required, and the arms are locked in either position. In the Mills pneumatic gate, a rubber diaphragm in an iron case attached to the gate post is used instead of a cylinder and direct air. One stroke of the pump by the gateman operates the arm or arms on one side of the track, thus requiring two strokes to close both sides of the crossing, and so reducing the liability to shut in a vehicle by carelessness. One diaphragm of each pair closes the gates, and the other opens them, motion being transmitted to the mechanism in the opposite gate posts by means of a rod, chain and bell cranks in each post, connected by rods underground. These gates are made by the Pneumatic Gate Co., of Chicago, and Bogue & Mills, also of Chicago.

For street crossings having tracks for horse, cable or electric cars, there should be provided some means of automatically stopping or derailing the cars if they run past a certain point when the gates are closed, as many accidents occur through carelessness or neglect on the part of the car drivers, conductors and gatemen. The ordinary rules are that the

car must be stopped and the conductor walk ahead at the crossing to see if it is safe, but he may be neglectful or his view may be obstructed by steam, smoke or moving cars. Derails or stop blocks, interlocked with the gates should be used, and with electric railways the current may be automatically cut off from the wire for a short distance on each side of the crossing. The increased weight, speed and momentum of electric cars as compared with horse cars, and the numerous accidents and narrow escapes at crossings, have made it evident that the crossing of a steam railway and an electric railway should be as efficiently protected as a crossing of two steam railways, and should be under the same regulations as are now required by state laws for the latter. This is specially important in view

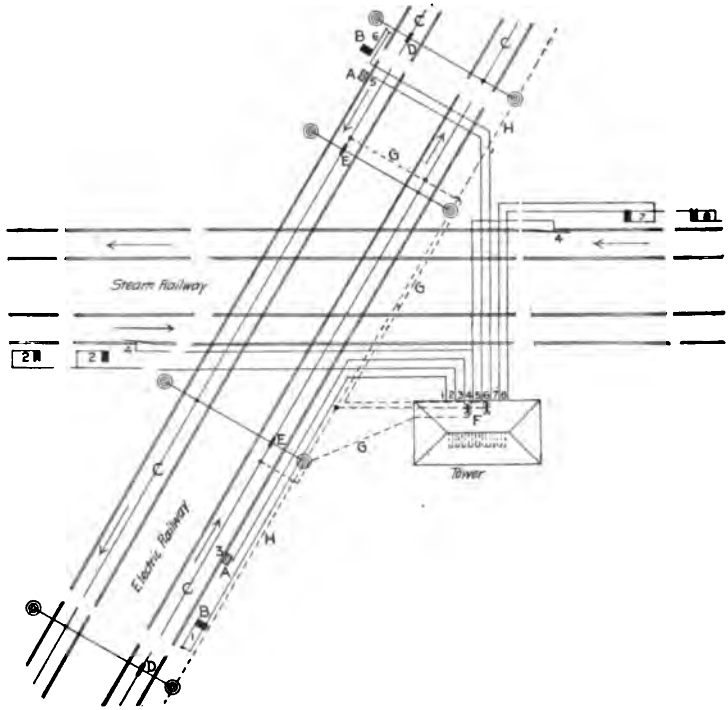


Fig. 96.—Interlocking of Grade Crossing of Steam and Electric Railways.

of the great development of suburban and country lines of electric railways, on which cars are run at high speed, being unobstructed by road traffic as in city streets, and it is matter of congratulation that in some states there has been a check put upon this multiplication of grade crossings by electric railways, and some over or under crossing is insisted upon.

An apparatus designed by Mr. Gibbs, of the Chicago, Milwaukee & St. Paul Ry., and used at a number of crossings of steam and electric railways, has the ordinary interlocking of signals, but also provides for cutting off the current and raising stop blocks when the signals are set for the steam railway. In Fig. 96, A is the stop block (about 50 ft. from the crossing), and B the signal for the electric railway. At a suitable distance

(500 to 1,000 ft.), from the crossing, the trolley wires C C, are broken by the insertion of a circuit breaker, or insulating block D, and at a point about 30 ft. from the crossing, another circuit breaker E is inserted. A feed wire for this insulated section D E is run to the electric switch F (in the tower), which is connected to the lever of the interlocking machine, and is supplied with current by means of the wire G which taps the main line feeder H. Thus, by opening or closing the switch, current may be cut off from or supplied to the insulated trolley wire section. The insulated section is thus terminated a few feet from the crossing; which insures a "live" section over the crossing at all times, making it impossible for a careless towerman to cut the motive power from a car which may happen to be on the crossing when a clear signal is given for the steam road. The devices on both roads are interlocked in such a way that before a clear signal can be given for the steam road the current must be cut off on the electric line approaches, the signal B set at danger and the stop blocks A raised. Warning of the approach of an electric car is given to the towerman by an annunciator consisting of a local battery bell circuit, actuated

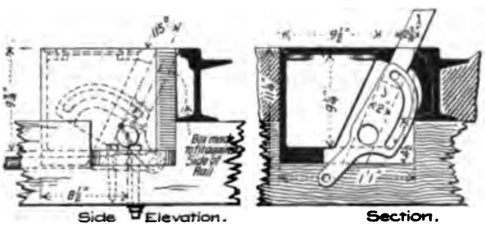


Fig. 97.—Stop Block for Street Railway Track at Grade Crossings.

by a relay placed in the loop of the trolley wire, which is brought into the tower. As soon as a car using current passes into the insulated trolley wire section, the magnet of the relay is energized and closes the bell circuit, giving the alarm.

The stop block, Fig. 97, consists of a cast-iron box, set outside of the rail and bolted securely to the ties, so that its top is flush with the street paving. In the top of the box and against the rail is an opening 2×4 ins., in which is set a wrought iron bar, I. This bar is raised and lowered by means of the slotted crank J, connected by a pipe line to the tower. The crank has a throw of 4 ins., the bar in its derailing position projecting this distance from the box and over the rail head. The slotted crank has a shoulder, and in its upper position the square end of the bar rests upon this shoulder in line with the axis of the arm and crankpin. The bar is therefore locked in its extreme position and the downward thrust of a car wheel is taken upon the strong pivot pin without bringing the strain upon the pipe line connection. A horizontally sliding plate to act as a derail may be used instead of the stop block.

Track Crossings.

Track crossings at grade were freely adopted in the early days of railway construction, but it is now generally recognized that every such crossing is a point of danger, and causes more or less interference with traffic, and more or less increase in maintenance work. There is therefore an increasing tendency to eliminate such crossings on busy lines, and enormous sums of

money have been expended in the separation of grades, which expenditures have been fully warranted by the increased safety and freedom of the traffic. At Mantua, near Philadelphia, Pa., the four tracks of the New York and Philadelphia divisions connected with the line leading to the Broad St. terminal station in such a way that all passenger trains had to cross the through main tracks at the freight yards, causing numerous delays, and also causing complication in handling the enormous number of freight trains at that point. This has been avoided by lowering the passenger tracks of the New York Division on a grade of 0.5% until they can pass under the yard at 1%, and then rising again by a grade of 1.2% to the normal grade. The crossing of trains at junctions, especially on four-track lines, has also been avoided in some cases by carrying one track over or under the normal grade. Such improvements not only facilitate the traffic and ensure safety, but also reduce the expenses for maintaining crossings, switches, derails, interlocking plant, etc. In the building of new railways there should be some legislative restriction as to the right to cross existing roads at grade, thereby interfering with the traffic of the

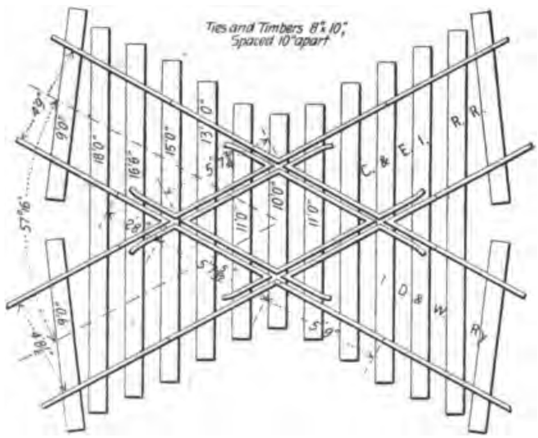


Fig. 98.—Track Crossing Laid on Ties and Long Timbers.

latter and conferring upon it no corresponding benefit. The new road might well be required to pay the cost of the entire construction of the crossing, with signals, interlocking plant, etc., subject to the approval of the officers of the existing road; and to pay also the expenses of watchmen, signalmen, etc. With such requirements greater care would be taken to avoid such crossings, and there are comparatively few cases where they could not be economically avoided without much additional expense, especially if the constant expense of their operation and maintenance is taken into consideration. The construction of the crossing frogs has already been described, and it is, perhaps, best to rivet them to base plates, particularly where they carry heavy traffic, but the riveting must be good and substantial work or the rivets will work loose and the frogs will clatter. The rails and frogs may be supported in either of three ways: (1) By ordinary ties placed at such angles as to afford the best support to all the rails; (2) Upon long switch ties or timbers; (3) By framed timbers which are halved together under the crossing frogs and give a continuous bear-

ing to each rail. Where ties are used at a right-angled crossing they are usually laid at an angle of about 45°, but the arrangement cannot be anything but unsightly, and is inferior to the second plan. The third plan is the most substantial, especially for angles of nearly 90°, and it affords the best resistance to lateral shifting or creeping of the crossing. Where a main line crosses a minor line at right angles, one track may have a longitudinal timber about 6 x 10 ins, or 10 x 12 ins., 12 to 14 ft. long, under each rail, while the other track has ordinary ties. Tie-plates should be placed on the longitudinal timbers.

The Chicago & Eastern Illinois Ry. uses ties and long timbers, 8 x 10 ins., spaced 10 ins. apart, as shown in Fig. 98, for crossings of less than 75°; and uses framed timbers for other angles. The Chicago, Burlington & Kansas City Ry. usually employs sawed ties 6 x 9 ins., except at right-angle crossings, where framed timbers are used, as shown in Fig. 99. The East Tennessee, Virginia & Georgia Ry. uses timbers 8 x 10 ins., of the required length, resting on a bed of ballast 18 ins. deep and properly drained, the timbers being placed at such an angle as to cross both tracks to the best advantage. The Burlington, Cedar Rapids & Northern Ry. uses switch ties for crossings at angles up to 80°. On the Louisville, New

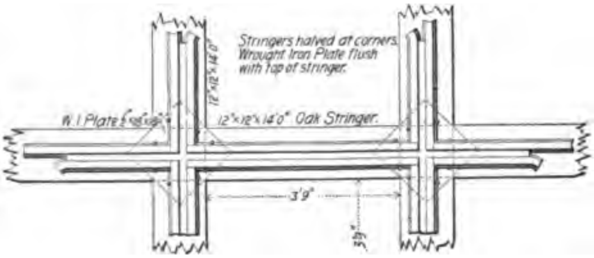


Fig. 99.—Track Crossing Laid on Framed Timbers; C., B. & K. C. Ry.

Albany & Chicago Ry., timbers 7 x 9 ins., 6 ins. apart, are used at all crossings, except those of over 80°. Under the timbers, the earth and old material are dug out and replaced with broken stone or gravel to a depth of 6 to 12 ins. on banks, and even deeper in cuts, where the drainage is bad; while tile drains are sometimes laid. The New York, New Haven & Hartford Ry. uses framed timbers in all cases. It is very important to have a thoroughly good foundation at the crossing, and there should be a plentiful supply of good ballast. At small "know-nothing" or unprotected crossings, where all trains are required to come to an absolute stop before reaching the crossing, there is likely to be increased wear of the rails, due to the frequent stopping and starting of trains, especially if the tracks are on a grade and the engines use sand. The extent of the wear will vary with the local conditions of grade, speed, traffic, etc.

All important crossings should be equipped with interlocking plant for home and distant signals and derailing switches, but local conditions must govern the application of these switches, as in some cases they may be very dangerous. Every interlocking plant should have both home and distant signals. If an engineman finds the distant signal clear he knows he has the right of way over the crossing, but if he finds it against him he slows down and runs under control, expecting to be stopped by the home signal. The derailing switch should be not less than 300 ft. from the cross-

ing on level track, while on a double track line there should be a "back-up" derail, 150 to 300 ft. beyond the crossing. The home signal may be 150 to 200 ft. from the crossing, and the distant signal 1,200 to 2,000 ft. from the home signal. The location of the signal and derails will depend upon the speed of trains, grades, etc., but the distant signal should be so far back as to give room for a fast train to be stopped before reaching the home signal, while the derail should be just beyond the home signal, but so far back that a derailed train will not be likely to reach the crossing. The derail may open to a short curved spur ending in a sand bank, so as to turn the train away from the crossing. It should be distinctly understood by all enginemen that the towerman is the man in authority at the crossing and can give the right of way to which train he pleases (subject, of course, to the general instructions given him), and the engineman has simply to look out for the signals and obey them implicitly.

Crossings of small country lines with little traffic are often left entirely unprotected, except by "slow boards" or signs. If near a station there may be a gate or horizontal bar swinging around a vertical post, and having a target or lamp on it; one or other of the tracks being always blocked. Lifting gates, as used at road crossings, are also used in some cases, being so interlocked that only one road can be cleared at a time. One form of protection for the crossings of steam and electric railways has already been described under the heading of "Road Crossings." A simple interlocking system for grade crossings of main lines by smaller lines or electric railways, consists in equipping the less important track with derailing switches standing normally open, these derails being interlocked with the signals of the main track. In a system of this kind at a crossing of the St. Louis, Keokuk & Northwestern Ry. by a small single track line, the latter track is fitted with derailing switches, which must be held closed by a trainman to allow the train to reach the crossing. When a train on either main track reaches a point half a mile ahead of the Hall automatic signal governing the block in which the crossing is located, it causes an indicator to be displayed at the derailing switches, giving warning of the approach of a train having the right of way. If the train on the single track finds that no main track train is approaching the trainman closes the derailing switch, and thereby sets the main track block signals at danger, thus showing that the crossing is occupied.

CHAPTER 10.—TRACK SIGNS.

Various warning and marking signs are required along a line of railway, to indicate distances, danger points, special points, etc., for the guidance of enginemen, property agents, etc. These signs should be strong and durable, simple in design, economical in construction, free from ornamental molding or painting, of as few different styles as practicable, and designed specially with a view to being conspicuous and easily recognized. Those which mark boundaries, right-of-way lines, etc., should be less conspicuous than those intended for the information of enginemen and others. The signs which are for the guidance of enginemen should be set at a uniform distance from the track, and at a uniform height above the rail, the length of post therefore varying on cuts and banks, but this

cannot be universally observed. Mile posts, for instance, are often placed on the right of way, beyond the toe of the bank, instead of on the slope. These signs should be on the engineman's side (right-hand side) of the track, except where side tracks or buildings interfere. They should never be less than 6 ft. clear from the nearest rail, and 8 ft. is a better distance, some roads specifying 6 ft. 6 ins. on embankments and 8 ft. in cuts.

The signs may be either simple posts, or posts carrying boards of various sizes. On many roads posts of different sizes and shapes are used for a variety of purposes, and these signs have the advantages of simplicity and low cost, but they do not allow of as much lettering as is sometimes required; besides which they are not conspicuous enough for some of the most important signs. Boards or flat signs may be of wood, cast iron or sheet iron. Wooden board signs are usually of 1-in. plank, and if of large size they should have battens about 1 × 3 ins. screwed to the back. Iron straps or wooden strips may be nailed to the ends of the board, but the use of molding strips as a frame is not to be recommended. The boards are generally nailed, screwed or bolted to the post, and are sometimes let into the post, but this latter practice involves extra work in shaping the post. For a large board a strap or brace of wrought iron, ½ × 1 in., may be used, passing over the back of the post and having its ends secured to the ends of the board by ½-in. carriage bolts. Cast-iron plates, with raised letters or figures, are quite frequently used, being screwed to the posts. Small ones may be ⅜-in. thick, with rim and letters ⅝-in. thick, while large ones may be ⅝-in., and 1 in. thick. Iron posts with flat disk tops are very liable to be broken and cannot be repaired. A simple, cheap and effective sign has targets of heavy sheet iron fastened to wooden posts or to posts of old boiler tubes. Scrap material of little value can often be utilized to advantage in this way. Stone, in the form of posts or slabs, is sometimes used for mile posts, but rarely for any other signs.

The posts of signs should be set not less than 3 ft. deep in the ground, and deeper if the sign is high or the board large. The lower end should be coated with pitch or creosote to about 12 ins. above the ground line. The top should be cut pointed, slanting or rounded, so as to shed water, and sometimes a piece of thin sheet iron is nailed upon the rounded top, but this is rarely necessary. Cast-iron caps are objectionable; they serve no useful purpose, and are liable to become loose and fall or be knocked off, being then often broken, stolen or lost. Broken stone or small field stone piled around the base of the post looks neat, protects the post from burning grass, and tends to keep weeds from growing. The edges of square posts may be chamfered, but no other decoration or trimming should be attempted.

There should be as little lettering as possible, and the letters or figures should be large, clear and plain. If much lettering is required, it is a good plan to have letters of malleable iron, about ¼-in. thick, screwed to the post, so that an ordinary track laborer can renew and repaint them. Otherwise a regular painter may have to be detailed to this work. Where a word is placed vertically (and this is a poor practice as a rule), it should read downwards if the individual letters are upright and upward if they are horizontal. Caution boards with long worded warnings in small letters are of little practical use. They may serve to meet legal requirements in some cases, but nobody will stop to read them.

As to color, plain black letters and figures on a white ground is the most

common practice and is most conspicuous, but sometimes the lettering is white, on a black or blue ground. Two colors are usually sufficient for ordinary signs, but in some cases a third color is desirable for the backs of posts and signs which have only one running face, so that the backs may be less conspicuous and not mistaken for signs. Red and green (with white lettering) should be used for stop and slow signs, respectively. White is in general the most striking color, and should be liberally used for signs. It is also the best color for signal posts, as the brown and dull ochre colors sometimes used for such posts are less distinct, and tend to "kill" the bright colors of the signal blades. The signs and posts should be kept in repair and frequently painted, so as to be easily distinguishable.

On the Atchison, Topeka & Santa Fe Ry., all posts are painted with brown mineral paint below the setting line; this line is usually a narrow black strip, but is a white strip on yard limit and section posts, which have white faces narrower than the width of the posts. All posts and signs are painted mineral brown above the setting line, except where letters or figures are to be marked, in which case the face is white, with black border and lettering. The Chicago, Burlington & Quincy Ry. uses mineral red for the posts, except that mile and section posts are white. The distance figures on the mile posts are placed sideways, reading upward, which is an awkward arrangement. Where boards are on the posts they are white, with black block letters. The posts are 7⅛ × 5½ ins., and 12 ft. long, set about 3 ft. in the ground. Brown is not so much used on eastern as on western roads.

The signs used vary on different roads, but some of the principal ones are noted below. Besides these there are corner posts and monuments for right of way and property lines; signs for city, township, county and state boundaries; curve elevation posts; gate boards, "Shut this Gate," on farm crossing gates; caution signs, "Keep off the Track," at bridges and in cities, where people are likely to trespass; train caution signs, "Derailing Switch in this Siding," at the headblocks of sidings where such derails are provided; and miscellaneous temporary or movable signs, such as "Clean Ashpans Here," "Dump Ashes Here," etc. Signs for caution to persons or direction to enginemen, etc., may be board signs similar to that of the station sign of the Northern Pacific Ry., Fig. 119, but without the molding. On the Pennsylvania Lines is used a sign reading "Caution, Keep off the Track," at crossings or other places in cities and towns where persons are likely to trespass on the track. This has a ¾-in. board, 34 × 17 ins., with corners chamfered 4 ins., secured by two bolts to the top of a post 4 × 4 ins., 9 ft. long, set 3 ft. in the ground, and having the edges chamfered. There is a frame of ¾ × 1½-in. strips, and on the back are two vertical cleats, ⅞ × 4 ins. The post and board are black, lettered in white; "Caution" being in 3-in. letters, and the other words ("Track," on a line by itself) in 2½-in. letters.

Boundary Posts.—The Atchison, Topeka & Santa Fe Ry. marks its crossings of state lines by the form of sign shown in Fig. 100. It is of oak, set facing the track at a distance of 13 ft. from the nearest rail. The post is set 5 ft. in the ground. County lines may be marked by square posts like mile posts, set edgeways to the track, and township lines may be marked by round posts with faces flattened for the lettering, as in Fig. 101, which is that of the Pennsylvania Lines. City limits may be indicated by wooden or iron target signs.

Bridge Signs.—Bridges, trestles and large openings are usually numbered, for convenience of reference in regard to repair, etc. The numbering, however, should include every opening and waterway, however small. Where it is desired to introduce this latter plan without changing the original numbers for the larger openings, or where additional openings are to be provided, fractional numbers may be used for the intermediate or additional openings. The structures or openings may be numbered from divisional points or by miles and letters, as 250A, 250B, etc.; indicating the first and second bridges beyond milepost 250. The numbers may be on iron plates, about $15\frac{1}{2} \times 10\frac{1}{2}$ ins., or on wooden boards; the signs being attached to the portals of a through bridge, or to a post or ¾-in. iron rod, 4 ft. 6 ins. long, on the abutments of a deck bridge or a trestle. A flat post, like a "Whistle" post, is sometimes used, being placed on the bank or spiked to the side of a tie; while in other cases a wooden block of triangular section is spiked on top of the end of a tie, having the number marked on the inclined face towards the abutment. The Atchison, Topeka & Santa Fe Ry. uses for pile and trestle bridges a plank 2×12 ins., 4 ft. long, spiked to the side of a tie, while for Howe truss bridges it uses a plate of ⅜-in. boiler iron, 10×30 ins., with four ⅝-in. holes. The plank is painted brown, with a white patch having black edge and letters; the plate is black, with a white patch or panel and black figures.

Clearance Posts.—These are to indicate the nearest point at which the end of a car on the turnout may stand without fouling cars on the main track, this point being where the inner rails of the two tracks are 7 ft. apart in the clear. They are usually square oak stakes, about 4×4 ins., 3 to 4 ft. long, with 1 to 2 ft. above ground, or the top 4 ins. above the top of the rails. The clearance post of the Baltimore & Ohio Ry. is shown in Fig. 102. They are usually placed between the tracks, and as they are liable to be stumbled over by switchmen and yardmen they should be made clearly distinguishable, being painted white, with a flat or rounded black top. The top is sometimes painted red, but this is not good practice. The Canadian Pacific Ry. uses a tall post with a black cross arm having two white disks, and places this sign on the turnout side of the track.

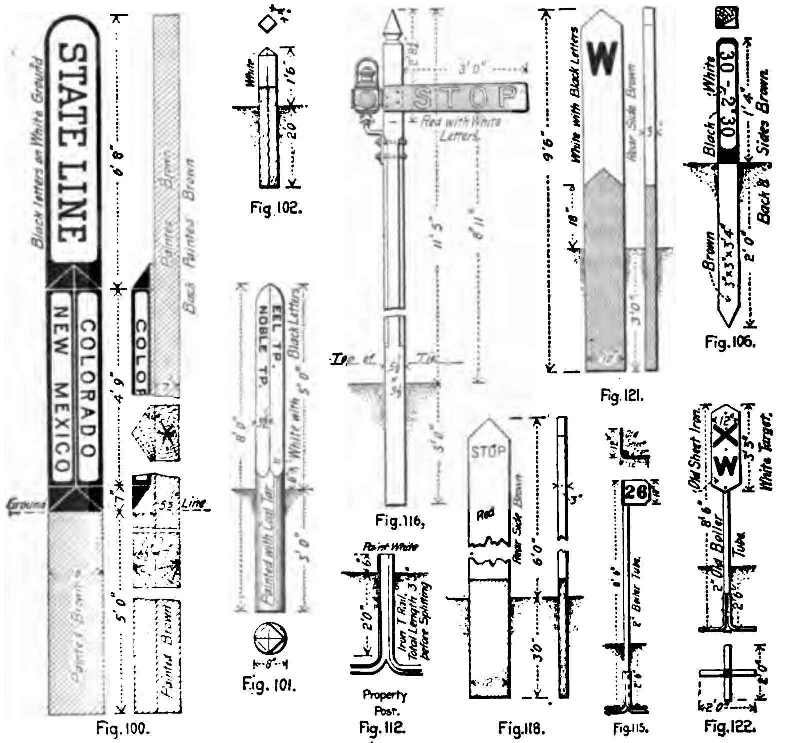
Crossing Signs (Highway).—These signs are erected at grade crossings to warn people on the highway to look out for trains. In some states the style and lettering are specified by law. Thus in Massachusetts and Vermont the sign must be placed across the road at such an elevation as not to interfere with the traffic, and the words "Look Out for the Engine" must be painted on it in letters at least 12 ins. high. The New York law requires boards to be placed across the road, elevated so as not to obstruct travel but to be easily seen by travelers, and on each side must be painted "Railroad Crossing; Look Out for the Cars" in capital letters, each at least 9 ins. high and of suitable width. Whether above or at the side of the road the sign should be so placed as to be conspicuously visible to persons approaching the track, but at the same time clear of such bulky traffic as wagon loads of hay, etc. A gong or bell, or other automatic signal, may be attached to a post at the crossing, as already noted. The sign should be large and distinct, though some roads use small boards or small cast-iron signs with inconspicuous lettering. The Pennsylvania Ry. uses large oval boards, on posts, with white letters on a black ground. The Maine Central Ry. uses a 1¼-in. board, 7 ft. 8 ins. long

and 12 ins. wide, let into the slotted top of a post 18 ft. long, set 4 ft. into the ground. The post is 10 x 10 ins. for 6 ft. from the bottom, and then diminishes to 8 x 8 ins. at the top, which is fitted with a cast-iron cap. The board is secured by two bolts. The post and board are painted white, and the board has a 3-16-in. black border stripe ¼-in. from the edge. The capital letters are 7¾ ins. and the smaller letters 5¼ ins. high. Three very common forms consist of a post carrying one horizontal board, two boards crossed at an angle of 45° to form an X, or four boards framed together in diamond form. The crossing signs of the Baltimore & Ohio Ry. and the Lake Shore & Michigan Southern Ry. are shown in Figs. 103 and 104, the former having a square post, and the latter having a post built up of planks. The words "Warning" or "Danger" or "Look Out for the Locomotive" may be lettered on the post, and should invariably read downward if the letters are vertical, and upward if the letters are horizontal or sideways. The letters on an 8-in. post may be 6 ins. high. The post should be of oak or cedar, and the boards of 1¼ to 2-in. pine, 12 to 20 ins. wide and 6 to 8 ft. long, lettered on both sides. These signs should be placed 10 or 15 ft. from the nearest rail.

Crossing Signs (Railway).—These are put up to warn enginemen that they are approaching a railway grade crossing. The Atchison, Topeka & Santa Fe Ry. uses a high post carrying two boards forming an X, facing the train and lettered "Railway Crossing," while on the post is lettered the distance to the crossing, "2,600 Feet." The Chicago, Burlington & Quincy Ry. sign is a board, 2 x 6 ft., lettered "R. R. Crossing, ½ Mile," this board being on a post 7½ x 5½ ins., 12 ft. long. In some cases a "stop" sign is put up near the crossing, there being then a mile (or half-mile) sign reading "Railway Crossing, One Mile," and then at 200 ft. from the crossing is a board sign reading "Stop; Railway Crossing, 200 Feet." Where the crossing has an interlocking plant the "stop" sign is not needed, but the mile sign may also have lettered upon it "Look Out for Signals," as in Fig. 105, which is the sign used by the Southern Pacific Ry. in connection with the interlocking system only. (See also Slow and Stop Signs).

Curve Signs.—On lines (or divisions) with numerous curves it is a good plan to number each curve, and this is very convenient in directing trackmen and others (especially new men) to any piece of work or any point where repairs are needed. For this purpose the Erie Ry. uses a small white board sign on a stake, close to the ground. This road also puts curve elevation stakes at the point of tangent and point of spiral curve, these stakes resembling clearance posts, and the latter having the elevation marked upon them. The Buffalo, Rochester & Pittsburg Ry. has all its curves marked by small signboards, 12 x 18 ins., attached to the telegraph poles, showing the number of the curve and the degree of curvature in each case. With one of these signs at each end of the curve an engineman can read it before reaching the curve, in whichever direction the train is running. The curves are numbered so that the roadmaster may be able to designate each one where he finds defects in the elevation, alinement or surfacing, as he rides over the road. In case of an accident, also, any particular place between mile posts can be designated in making reports. The numbering also facilitates the understanding of orders to slow down at certain curves. The degree of curve is marked on the sign so that the section men may be able to preserve the proper superelevation when they surface the track or test the curves with the level boards or

track levels, and may also be able to curve the rails to the proper middle ordinate when putting in new rails for repairs. It is convenient, too, for enginemen to be familiar with the degrees of curvature, so that on fast runs they may handle the air brakes so as to control the speed properly in approaching curves and running round them. The Atchison, Topeka & Santa Fe Ry. uses a post 3 x 3 ins., 3 ft. 4 ins. long, set 2 ft. in the ground and lettered on both sides. It is set on the right-hand side of the track in the direction in which the mile numbers run, being placed opposite the beginning of the curve and 2 ft. from the rail, with the lettered sides facing the trains. This is shown in Fig. 106. The curve elevation post of the



Track Signs.

Pennsylvania Lines West of Pittsburg, Fig. 107, is set 6 ft. from the rail, and is white, with black letters, the lower part being painted with coal tar.

Drawbridge Signs.—The Southern Pacific Ry. uses three signs each way from the bridge, all the signs being 3-in. oval boards, 48 x 36 ins., let into the face of the top of an 8 x 8-in. post 18 ft. long, set 4 ft. in the ground. The board is secured by three bolts with flat button heads, and has a band of hoop iron 1/8 x 2 1/2 ins. around the edge. The first sign is lettered "One Mile to Drawbridge;" the next, "1,000 ft. to Drawbridge;" the third, "All Trains Must Come to a Full Stop Before Crossing Drawbridge," this being lettered around the board, with "Stop" in larger letters in the middle. A similar arrangement is used for railway crossings.

Flanger Signs.—These are placed to indicate to the men in charge of snow plows and flangers where to raise the flanging blades to clear switches, etc. The Northern Pacific Ry. uses a black board, 12 x 24 ins., 1½ ins. thick, let flush into a white post, 6 x 6 ins., with the top 8 ft. from the rail. The board is not lettered, as these signs are, of course, only for temporary use, but the black board is very conspicuous against a background of snow. The post has the top cut sloping from the board, and has its corners chamfered. This sign is placed 8 ft. from the track, on the right-hand side, and 50 ft. in advance of the obstruction.

Junction Signs.—The Atchison, Topeka & Santa Fe Ry. puts up signs 2,600 ft. from junctions, these being identical in style with its railway crossing signs above described, but lettered "Railroad Junction."

Mile Posts.—These are most commonly timber posts, about 10 x 10 ins., 8 ft. long, set 3 ft. 6 ins. in the ground. The top may be beveled off in a low pyramidal shape, rounded and covered with tin, or flat and covered with a cast-iron cap. The mile post of the Baltimore & Ohio Ry., Fig. 108, is an example of this style. These coverings and caps, however, are better avoided, as well as ornamentation or cutting of the post, except, perhaps, the chamfering of the edges. The post is set either with one side or one edge towards the track, and may have the distance from (and the name or initial of) one or both of the terminal points painted on opposite sides. In some cases smaller posts are used with boards nailed to them, while where cheapness is specially desirable small board signs may be nailed to the telegraph poles. The Northern Pacific Ry. uses a 10-in. post of barked cedar, set on the north side of the track, 8 ft. from the rail. As shown by Fig. 109, there are two boards, 2 x 12 x 16 ins., let into the post, meeting at an angle of 60°, and having the names of the terminals of the division marked upon them, with the distances therefrom. The boards are secured by 20-penny nails. The post (above and below ground) and board are painted white, with black letters 3¾ ins. high and ⅝-in. thick, and black figures ¾ x 5 ins., with a margin of at least 1 in. The Atchison, Topeka & Santa Fe Ry. uses a plate of ⅜-in. boiler iron, 10 x 18 ins., secured to the telegraph pole nearest to the exact distance by means of two lag screws ½ x 3 ins., in ⅝-in. holes. These plates face the track, and are painted white, with black figures and border. On a few roads cast-iron posts are used, but these are rare.

Stone mile posts are used by several railways. The Boston & Albany Ry. has square granite posts, Fig. 110, with two sides dressed down 3 ft. from the top, and pene-hammered. The cost, with one letter and three figures cut on each dressed side, is about $5 per post. The Lake Shore & Michigan Southern Ry. uses larger stone posts, as shown in Fig. 111. The Maine Central Ry. uses a rough dressed stone slab, 12 ft. long, 20 ins. wide and 8 ins. thick, set 4 ft. in the ground, and having 30 ins. at the top dressed smooth for lettering. The unusual height is on account of the heavy snows in winter. The dressed faces are painted with three coats of white lead, with black lettering and a 5-16-in. black stripe. The post is lettered on both sides, thus: "249 Miles to Vanceboro" on one side, and "2 Miles to Portland" on the other. The New York, Pennsylvania & Ohio Ry. uses flat stone slabs, with the letters cut into them. The slabs are set edgewise to the track and are painted white, with the letters and lower part black. Similar slabs, but of smaller size and less height, are used for

half-mile and quarter-mile marks, but the use of such intermediate posts is not common in this country.

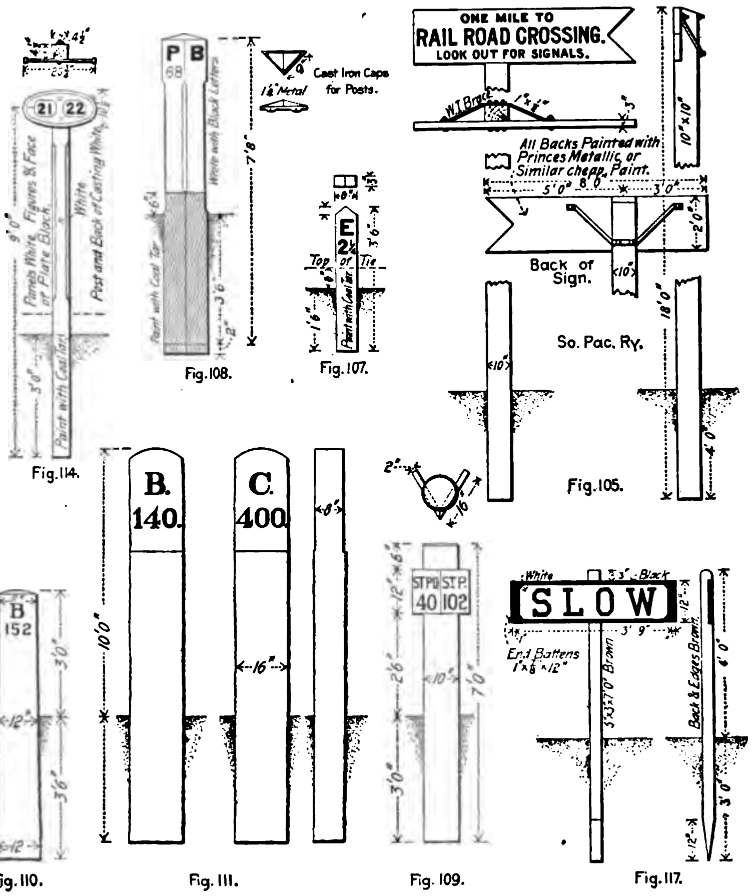
Premium Signs.—On roads having the track inspection and premium system, with annual awards for condition of track, a board sign (resembling a station name sign) is sometimes placed on the best section. A black board with "Premium Section" in gilt or yellow letters is a conspicuous sign for this purpose and may be erected on the section house or on posts at the section house or at a station on the section. There is no doubt that the men feel proud of such a trophy, and will work hard to prevent another section gang from winning it away from them.

Property Post.—The marking of property lines or right of way boundaries should be done very carefully, and permanent monuments should be established. The Baltimore & Ohio Ry. uses a piece of rail 3 ft. 3 ins. long, with the web split for about 6 ins., and the head and base bent out to form an inverted T, as shown in Fig. 112. The top projects about 6 ins. above the ground. The Lake Shore & Michigan Southern Ry. uses one of the best monuments that has come to the writer's notice for marking land corners, etc. As shown in Fig. 113, it is a cast-iron post, 2 ft. 6 ins. high, with the section of a cross, and having a top cap 2 ins. square and a circular base 8 ins. diameter. In the center of the cap is a ¼-in. hole, ¼-in. deep. All corners or angles in the boundaries of station grounds, etc, should be marked by posts, and if these cannot be set at the corners they should be set in the lines running thereto and have the distance plainly painted on the side facing the corner to be marked. These posts may be 8 ft. long, rough below ground, and 5 ins. square for the 3 ft. above ground.

Section Posts.—These mark the limits of track sections, and should be smaller and less conspicuous than signs to be observed by trainmen. The Chicago, Burlington & Quincy Ry. uses a post 7½ × 5½ ins., having the top painted. It is painted mineral red, with a white patch at the top and a black figure. On the Pennsylvania Lines West of Pittsburg, an oval iron sign, 10½ × 20¾ ins., is used, being secured by two bolts to the top of a post 4½ ins. square, Fig. 114. The plate has two panels sunk ⅛-in., with raised figures flush with the surface of the plate. The panels are white; figures and face of post, black; post and back of casting, white; it is set 7 ft. from the rail. The Southern Pacific Ry. uses a post, 8 × 8 ins., 8 ft. long, set with one edge to the track, and also uses iron signs of the style shown in Fig. 115, having a target of old sheet iron, 10 ins. deep, bent to form two faces 10 × 12 ins. at right angles to each other, one of these facing the track. At its corner the target is fastened to the top of an old boiler tube by three rivets. The Northern Pacific Ry. uses a 1-in. board, 24 × 13 ins., with a frame ¾ × 2 ins., and nailed to a post 6 × 4 ins., 7 ft. long, set 3 ft. in the ground. The board is painted white and has the word "Section" with the numbers of the two sections underneath in black letters and figures 3½ ins. high and ¾-in. broad. One of the simplest signs is a white board, 8 × 18 ins., on a post, with the numbers of the sections in black, but the Atchison, Topeka & Santa Fe Ry. dispenses with the board and uses only an oak post 2 × 6 ins., 5 ft. long, set edgeways to the track, 6 ft. from the rail, with the section numbers painted on opposite sides. The post is brown, with a white top having a black border and lettered "Sec. 123" and "Sec. 124," the letters reading downward. The post has a rounded top.

Sidetrack Limit Sign.—On long sidetracks, for use by two trains, a square post like a mile post, but without figures, is placed to mark the middle of the sidetrack, for the guidance of enginemen.

Slow and Stop Signs.—These are used at the approaches to track crossings at grade, drawbridges, etc., and are usually painted green and red, respectively, and lettered in white. They are usually either flat posts, about 3 x 10 ins. or 3 x 12 ins., or large boards on posts. Sometimes the



Track Signs.

boards are only about 4 ft. above the ground, but a greater height is preferable. On the Pennsylvania Lines West of Pittsburg, these signs are made consistently to conform to the standard positions of signals. Thus, one has "Slow" in white letters on an inclined green arm; and the other (Fig. 116) has "Stop" in white letters on a horizontal red arm. The arms are 3 ft. long and 8 ins. wide, with 6-in. letters, and are nailed to posts, the arms pointing to the right of the track. The posts carry switch lamps with green or red glasses. These signs are used where all trains must be under control,

or come to a stop, the "Slow" sign being set 2,000 ft. from the danger point, while track crossings have the "Stop" signs at a distance of 300 ft. in each direction. Where only freight trains are required to be under control, a post 3×10 ins. is used, 6 ft. high above ground, painted green, with "F. S." in 8-in. white letters. The Southern Pacific Ry. puts up the signs at 1 mile and 1,000 ft. from track crossings and bridges. Each of these signs (lettered "Slow" or "Stop") is an oval board 36×27 ins., 3 ins. thick, let flush into the top of a post 6×6 ins., 14 ft. long, set 3 ft. 6 ins. in the ground. The board has an iron band $\frac{1}{8} \times 2\frac{1}{2}$ ins. around its edge, and is secured to the post by two bolts, while a horizontal triangular cleat is nailed on each side to the post and back of the board. The "Slow" board

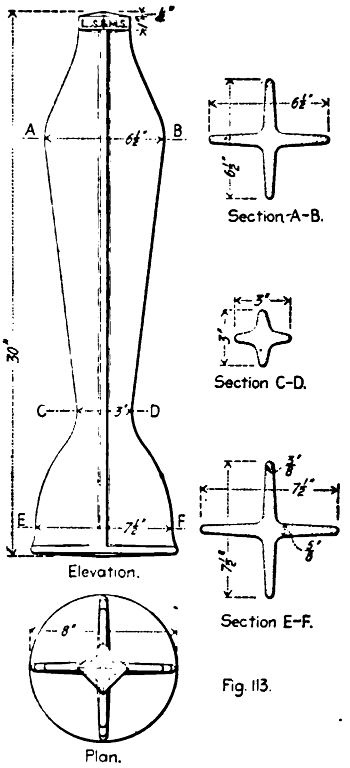


Fig. 113.—Property Monument; L. S. & M. S. Ry.

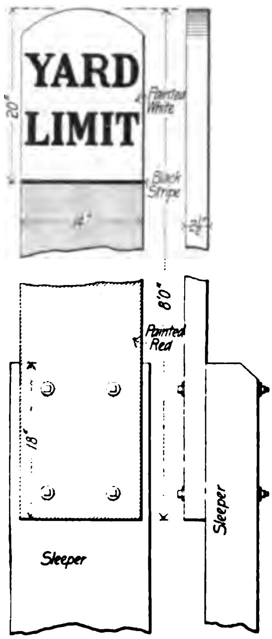


Fig. 123.—Yard Limit Sign; Maine Central Ry.

of the Atchison, Topeka & Santa Fe Ry. is shown in Fig. 117, and the "Stop" post of the Baltimore & Ohio Ry. in Fig. 118. The Southern Pacific Ry. also puts near the crossing or bridge a sign with the words "All Trains Must Come to a Full Stop Before Crossing Railroad Track" (or "Drawbridge"), the word "Stop" being in large letters. So much lettering, however, is undesirable, unless to meet legal requirements.

Station Signs.—On some roads a sign is placed one mile from each station, being usually an oval or rectangular board, painted white, with "One Mile to Station" or "Russell, One Mile." lettered in black. Whistle posts

are also usually placed half a mile from the station, directing the engineman to whistle for the station. These signs should be placed a mile and half a mile, respectively, from the outer switch of the station yard, or from the yard limits. The Chicago, Burlington & Quincy Ry. has a post 7½ × 5 ins., with a cross-piece of the same size, 3 ft. long, lettered "Sta. ½ Mile." A common style is that of the Northern Pacific Ry., Fig. 119. The board is 10 × 10 ins., 1-in. thick, with a frame 1 × 3 ins., and a 1-in. molding strip. This is carried on a post 6 × 6 ins., 12 ft. long, set 4 ft. in the ground, and placed 10 ft. from the rail. The post and board are white, with black letters, frame and molding. The letters and figures are 5 ins. high, 1⅛ ins. thick, with a 2-in. margin, and 3½ ins. between lines. The Atchison, Topeka & Santa Fe Ry. uses an oak post, 3 × 10 ins., 11 ft. long, set 5 ft. 2 ins. in the ground, and bearing the word "Station."

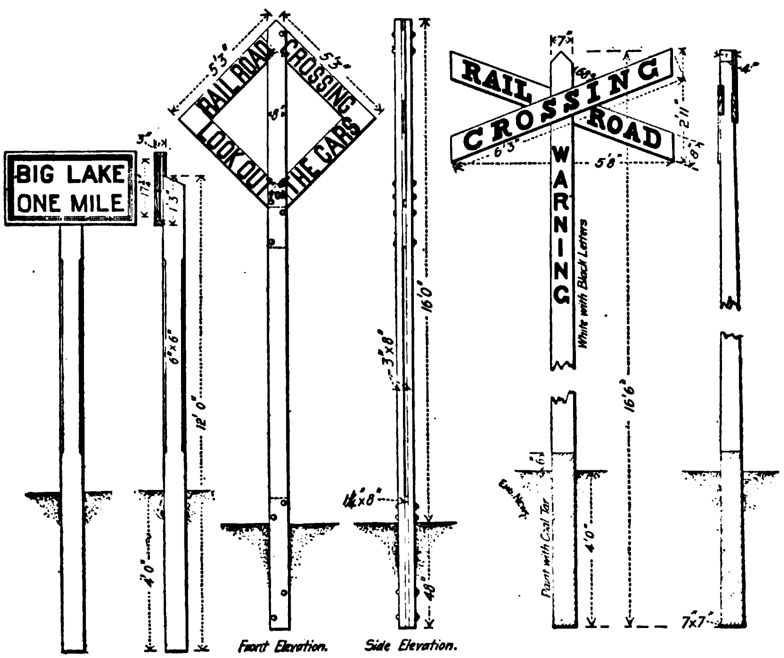


Fig. 119. Fig. 104. Fig. 103.

Track Signs.

Station Name Boards.—These should be large, boldly lettered and conspicuously placed. No advertising signs should be placed near them, and no advertising signs of similar style should be allowed. They are frequently placed so that at night (or even by day) they cannot be seen from the cars, as for instance, when they are placed on the eaves of the platform roof. They should be set back from the track, and have lamps specially placed to illuminate them, while it is also a good plan to have glass name slips in the windows of the agent's office, waiting room, etc. The sign should be not less than 18 ins. wide, the length varying with the name to be painted on it. The distances to the terminals or divisional points may be painted on each end of the board, before and after the name.

Fig. 120 shows the station sign of the Atchison, Topeka & Santa Fe Ry., east of Denver, and where there is no station building the sign is bolted to two posts, 6 x 6 ins., with chamfered edges, the posts being 15 ft. long, and set 4 ft. in the ground. At stations this sign is attached to the side of the building facing the track, with the bottom 8 ft. above the platform wherever practicable. The iron panel strips are ⅝-in. shorter than the distance between top and bottom boards, and placed so that their ends are 3-16-in. from these boards. The board is 12 ins. wide and ⅞-in. thick, with frame boards 1⅛ x 2½ ins. The station sign of the Maine Central Ry. is made up of two thicknesses of ⅞-in. pine boards, the back board 25 ins. wide at the middle and 19¾ ins. at the ends, and the face board slightly smaller. The boards are put together with four screws, and have their edges beveled or chamfered. The face of the board is painted black and sanded; the letters are white, with gilt edging, and over the corner screws are 1½-in. gilt caps. There are also some flourishes in gray, but these might well be omitted. For the convenience of passengers it is an excel-

Fig. 120.

Fig. 120.—Station Name Board; A., T. & S. F. Ry.

lent plan to make the name of the station in large clear letters of white stones, shells, flowers, etc., on a turfed strip or a leveled surface of cinders just beyond the platforms.

Water Station Signs.—At stations having water tanks for the engines, the words "Water Tank" may be painted on the one-mile station sign, while for tanks between stations a special board sign with "Water Tank, One Mile" (or "Water Station"), may be put up. The Chicago, Burlington & Quincy Ry. uses an upright sign, 2 x 3 ft., "Water, ½ Mile," set on the standard size of post, but oval boards are more common. The end of a track tank nearest the approaching train is usually marked by a large iron disk, with a target, painted green, mounted on an iron rod, which also carries a green switch lamp at night. This is to indicate to firemen when to lower the tender scoop, a similar signal being placed about 100 ft. from the leaving end of the tank to warn the fireman to raise the scoop if he has not already filled his tank.

Whistle and Ring Signs.—These are usually set ¼-mile on each side of the road crossings and ½-mile or 1 mile from stations, placed on the engineman's side of the track; or on the right hand side on single track and left hand side on double track. They may be flat posts, 10 x 3 ins. or 10 x 4 ins., with the top cut to a point or rounded, and the corners sometimes chamfered. The post is set with its edge to the track. The post of the Baltimore & Ohio Ry., Fig. 121, is of this style. Square posts, 8 x 8 ins., are also used. The length is from 8 to 12 ft., with 5 to 8 ft. above ground, the higher ones being used where deep snows occur. The posts are usually white, with a large black R or W (or both) 6½ ins. high, the sides and back being sometimes painted light blue, so as not to be conspicuous. In some cases the face is cobalt blue with white letters, or brown with a white panel and black letters. The Maine

Central Ry. uses a ¼-in. iron plate of diamond form, 28 x 21 ins., let 4 ins. into a 6 x 6 in. cedar post, whose top is 4 ft. 6 ins. above the ground, and is covered with a cap. The bottom of the plate is secured by four ½-in. bolts, the upper ones 7¾ ins. and the lower ones 7¼ ins. long. The post is painted black to a height of 2 ft. above ground and thence white. The plate is given two coats of red lead and four coats of white lead, and is lettered "Whistle Here" in English vermilion. On the Buffalo line of the Lehigh Valley Ry. a simple and neat sign is used, consisting of a diamond shaped piece of sheet iron, with its lower corner riveted to the top of a rod which is driven into a wooden plug in the iron pipe which forms the post. The pipe and target are painted black, with a white R or W. A somewhat similar arrangement is that used by the Southern Pacific Ry. for road crossing whistle signs, Fig. 122. It is painted white, with black letters, and the back is coated with some cheap paint. The X on this sign is to indicate that it is a crossing sign, and some roads put "S. W." on the station whistle posts. The Northern Pacific Ry. has a post 10 x 12 ins., 12 ft. long, set 4 ft. in the ground, having the top rounded and the edges chamfered 1 in. all round from 8 ins. above the ground. The post is painted white for 9 ft. from the bottom, then black, with a white W 9 ins. high., its top being 12 ins. from the top of the post. For a post 10 or 12 ins. wide, the letters should be about 9 ins. high and 8 ins. wide, with lines 1½ ins. thick, plain black letters should be used. "Whistle and Ring" signs (lettered W. R.) are used at places where it is necessary to give warning to track and bridge men of the approach of trains; these should be 1,000 ft. distant from the point to be warned.

Yard Limit Signs.—These denote the limits covered by the yard gangs, and to which switching engines work. All trains (except those of the first class) are usually required to stop at them before entering the yard, unless the track is plainly seen to be clear (see chapter on "Yards"). Sometimes a flat post about 3 x 12 ins. is used, painted brown or dark red, and having a white patch or panel lettered "Yard Limit" in black. The Chicago, Burlington & Quincy Ry. uses a board 24 x 38 ins.. as its standard post with the name of the station: "Aurora; Yard Limit." On the Pennsylvania Lines West of Pittsburg, is used an oval cast-iron sign. 33½ x 20 ins., 4 ft. 6 ins. above the ties; it is painted green, with white letters 2⅞ ins. high. The Atchison, Topeka & Santa Fe Ry. uses a post similar to its station post. It is painted brown with a white panel having a black border and "Yard Limit" lettered downward from the top in horizontal letters. The Maine Central Ry. sign is a 2½-in. plank, 14 ins. wide and 8 ft. long, with the bottom bolted to a post or sleeper. The lower part is red and the upper part white, with black letters and a black stripe. The Southern Pacific Ry. has a post 6 x 6 ins. carrying a board 27 x 42 ins.; lettered "Yard Limit" in black letters 6 ins. high.

CHAPTER 11.—TANKS AND OTHER TRACK ACCESSORIES.

Tanks and Water Columns.

The construction, erection and maintenance of these structures frequently come more or less under the charge of the track department, and may, therefore, be given brief mention here. The most common form of water tank is of wood, with vertical staves, bound by iron bands, and supported on a masonry tower or upon columns of wood or iron. A very general size of tank is about 16 ft. high and 24 ft. diameter, the capacity being 50,000 gallons. Iron tanks are not extensively used in this country. Where engines take water directly from the tank, a horizontal pipe from the side or center of the bottom of the tank leads to a hinged spout which may be let down to lead the water from the pipe to the tender manhole. This spout sometimes has a loose vertical end of pipe, or has a piece of rubber or leather hose attached to the end which falls into the manhole and prevents splashing. The spout is counterweighted to stand vertically, being usually pulled down by a chain which is within reach of the fireman when standing on the tender. The valve in the pipe leading to the spout is operated either by a chain or lever within reach of the fireman, or by a hand wheel on a stand near the ground. The pipe and spout should be of ample capacity, so as to fill the tender tank as quickly as possible, and the discharge will be facilitated if the tank is elevated as much as possible above the engine. A float in the tank connected with a ball sliding on a staff on top of the tank or with a pointer moving on a vertical graduated scale fixed to the side of the tank shows the level of the water.

Many old water stations have too small a discharge, so that fast trains are delayed unnecessarily while taking water. Where this is recognized, considerable improvement has been effected. The Chicago & Northwestern Ry. puts its tanks at least 20 ft. above the track, and uses 12-in. cast-iron pipe to connect with the 10-in. standpipe or water column. By this means a discharge of 4,000 gallons per minute is obtained. Provision must be made against leakage, or in winter there may be a pile of ice across the rail which may perhaps cause a derailment.

The supply pipe leading up the tower to the tank is usually boxed in and protected from the weather. If a steam pump is near at hand a steam pipe may be led into the chamber enclosing the pipes, or otherwise a stove may be placed therein. During extremely cold weather the section foreman is often called upon (through the roadmaster) to furnish a man to look after the water station.

The tank may be supplied by a steam pump of suitable capacity, or by a pump driven by a wind engine. An automatic arrangement has also been introduced by the Automatic Water Tank Co., of New York, by which pumps are dispensed with. In the well is placed a closed iron tank of the same capacity as the ordinary elevated tank, and from this a suction pipe extends to the water, while steam and water pipes extend up to the surface of the ground and have hinged connections to reach to the tender. The steam pipe is coupled up to a pipe on the engine, and when steam is turned on it starts the flow of water. A tender tank, of 2,800 gallons capacity.

may be filled in about three minutes, and the elevated tank (for use in emergency) will be automatically refilled.

The quality of the water supply of a railway is a very important matter,

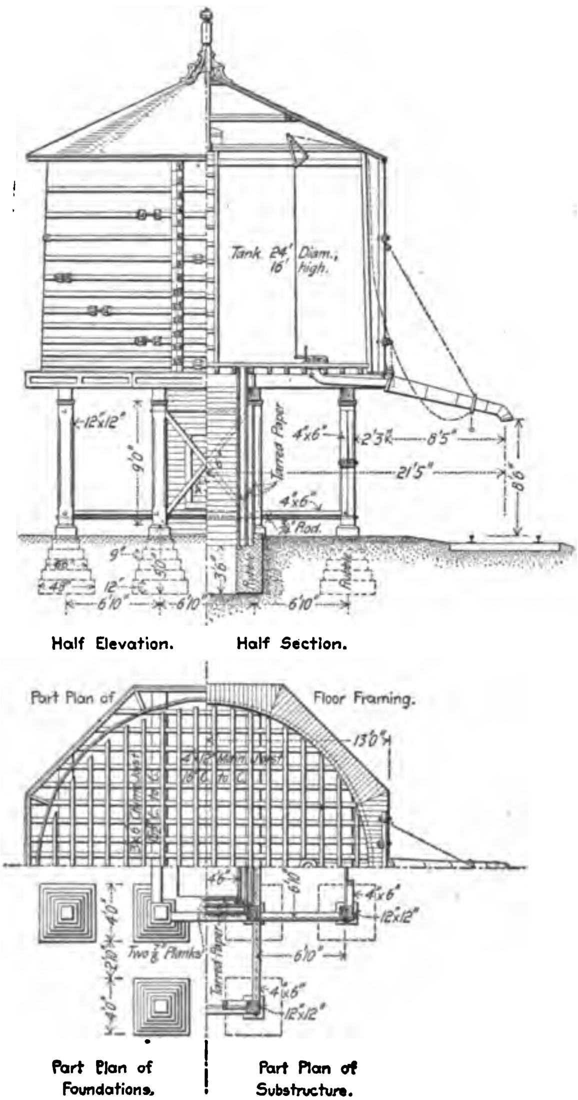


Fig. 124.—Water Tank for Supplying Locomotives.

affecting the life of the boilers and the steaming capacity of the engines, and in consequence of a bad local water supply the Long Island Ry. supplies the tanks, etc., at Long Island City, from wells 10 miles distant by

means of a pipe line of 10-in. and 8½-in. pipe, and a pumping engine of 2,000,000 gallons daily capacity, as described in "Engineering News," New York, Feb. 20, 1896. A plan for chemical purification, introduced by the We-Fu-Go Co., consists in using two tanks, the bottom of one being level with the top of the other. The water is first pumped to the upper tank, passing through a chamber containing a suitable portion of a chemical and is then stirred mechanically for 15 or 20 minutes. After settling this tankful of water

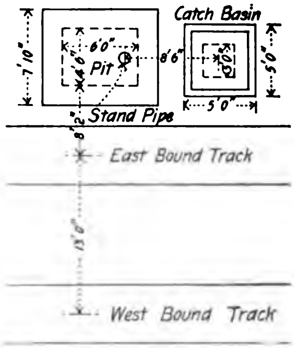


Fig. 125.—Location of Water Column.

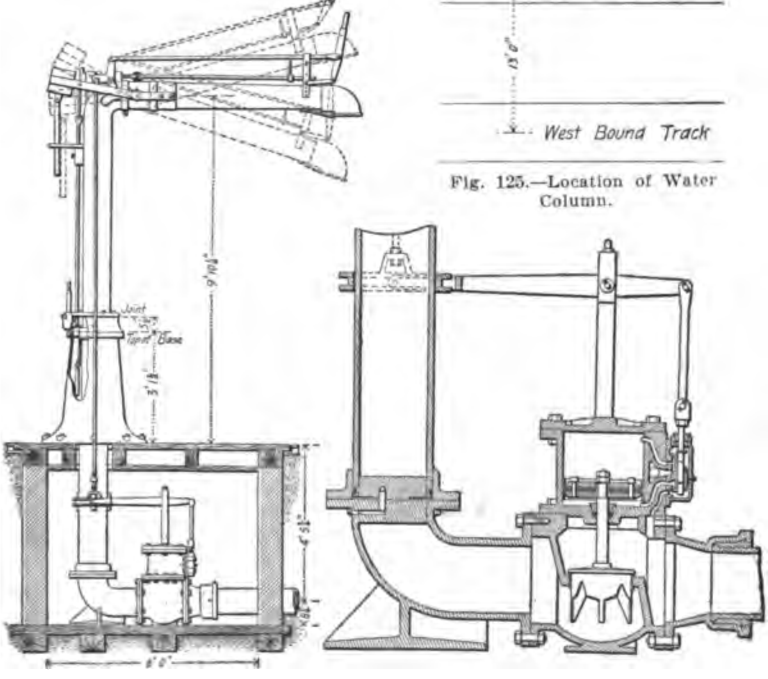


Fig. 126.—Sheffield Water Column.

passes to the lower or storage tank, ready for the engines, and the upper tank is again filled. The cost, of course, depends largely upon the character of the water to be treated.

Where it is not convenient to run the engines to the tank, or where engines on several different tracks have to be supplied, two tanks may be erected and connected by a horizontal pipe crossing the tracks, this pipe having a suitable hinged spout and valve over each track. The common

practice, however, is to use water columns or stand-pipes, placed beside and between the tracks, each having a horizontal swinging pipe arm at the top, the columns being supplied from the tank by a pipe which should be not less than 8 ins. diameter. The arm should swing automatically back to position parallel with the track. In some columns the swinging arm can be depressed so that its end enters the tender manhole, no leather hose being used on the pipe. The shocks due to the sudden shutting off of the water at these columns may be avoided by the use of a valve operated by the fireman on the tender by means of a hand screw on the end of the spout, so that the valve cannot be closed suddenly. Fig. 124 shows a standard tank for watering engines direct. The tank used by the Lake Shore & Michigan Southern Ry. for feeding water columns is on a braced wooden tower 30 ft. high, the center part being enclosed by a 12-in. brick wall to form a chamber for the 8-in. pipe which conveys the water to the column. The arrangement of the water column is shown in Fig. 125.

The principal makes of water columns are the Sheffield, Dodge, Poage, Mansfield and Smith, the first of which (made by the Sheffield Car Co., of Three Rivers, Mich.) is shown in Fig. 126. The spout of the Sheffield stand-pipe is movable in a perpendicular plane, this movement being obtained by a rubber joint. The weight of the spout is carried on a wrought-iron hinge, which plainly shows by its pivot in the center of the joint, and the rubber is vulcanized to a special point which has been found by experiment to resist both cold and atmospheric influences. The mouth of the spout is of copper or brass, with a nose piece preventing the spout from catching in the manhole of the tender, when depressed for the purpose of taking water, in case the engine should be accidentally started. By the raising of the spout when the engine has ceased taking water all drip is retained within the pipe and carried to the pit, where it automatically drains away. The pipe is supported by a high bell casting. A gravity lock is provided so that when the pipe is rotated to a position parallel to the tracks it automatically locks itself in place, a dog dropping into a slot so that the pipe cannot be blown about by the wind, nor can the pipe be operated by unauthorized persons until the lock or latch is released from its fastenings by lifting from the notch which holds it. It is also arranged that by means of a link this latch may be locked by the use of an ordinary switch lock, so that the pipe cannot be released until this lock is opened by a switch key. The drain pipe is so arranged that there is no drainage of water until the pipe is rotated to a position parallel to the track, thus avoiding all wastage of water except that contained in the pipe itself at the time of shutting off the flow. The valve ordinarily used is a globe valve, shut against the pressure of water by a quick opening screw, operated by a hand wheel; in case of severe pressure a straightway valve is furnished, and as a further precaution a spring relief valve may be provided. This valve is of two forms, the first being a simple valve controlled by a spring, the other being automatically regulated by the pressure of water in the main so as to open and close more slowly with increased pressure, this being desirable where the pipe is adapted to city mains, upon which there are at different times quite sharp changes of pressure. In place of this relief valve an air cushion, for absorbing the shock due to water hammer in case the valve is closed too fast, may be furnished, this being in some cases preferable to either a spring or the automatic hydraulic relief valve. The valves of these pipes are made in-

terchangeable and fastened in place by flanges and bolts so that any one of them can be removed at any time without altering the position of the pipe.

The pipe is furnished in four sizes, 6, 7, 8 and 10 ins. diameter. The No. 1 pipe is the automatic style, so called, which is operated from the tender by the fireman. The cut shows clearly the method of operation. The spout, bell support, counterweight, rubber joint and drain valve, also the automatic locking device, are the same as in the plain pipe heretofore described, except that the latter is operated by a lever from the tender instead of from the ground, although it can also be released from the ground if desired. The rod operating this is shown having a universal coupling made above the rubber joint. The valve is operated by the pressure of water in the main, this operation being obtained by means of a hydraulic cylinder located over the valve, the area of the piston being very considerably larger than that of the valve, and the ingress and egress of water for the hydraulic cylinder being controlled by a slide valve; the exhaust is controlled by a small stop-cock which can be opened or closed to any degree required, so as to secure slow closing of the valve when this is important. The slide valve is operated, as will be seen, by a lever on the end of the spout by means of a rod and elbow joint.

The method of operating the valve by the pressure of water in the main is a leading feature of these pipes, and by this means ample power is always attained, and the opening and closing of the valve is entirely out of the control of the fireman, that is as to speed, it being set to open and close as may be found best by the man in charge of water service. Ample means are provided for the taking up of lost motion wherever any wear may occur.

Pumps.—The water supply may be delivered to the tanks by pumps driven by wind, gas or steam. The Halladay windmills, made by the U. S. Wind Engine & Pump Co., of Batavia, Ill., have wheels 8 to 30 ft. diameter, running at 54 to 26 revolutions per minute. The pumps have cylinders 2 to 10 ins. diameter, with a stroke of 3½ to 24 ins., the capacity per stroke being as follows:

Cylinder, ins.	Delivery per stroke, gallons.	Cylinder, ins.	Delivery per stroke, gallons.
2 × 4	.052	4 × 8	.422
2½ × 5	.102	5 × 10	.835
3 × 6	.178	6 × 15	1.814
3½ × 7	.284	10 × 24	8.040

With double-acting pumps the delivery will, of course, be doubled. The diameter of the pipes should be half that of the pump cylinders, or rather larger for double-acting pumps and long pipes. The capacity of some standard sizes of Knowles steam pumps for this class of work is as follows:

Steam cyldr, ins.	Water cyldr, ins.	Stroke, ins.	Delivery per stroke, gallons.	Strokes per minute.	Delivery per minute, gallons.	Steam pipe, ins.	Exhaust pipe, ins.	Suction pipe, ins.	Delivery pipe, ins.
6	6	12	1.47	100	147	¾	1	4	4
6	7	12	2.00	100	200	¾	1	5	5
7½	7½	10	1.91	100	191	1	1¼	5	5
8	7	12	2.00	100	200	1	1¼	5	5
8	10	12	4.08	100	408	1	1¼	6	6
10	12	12	5.87	100	587	1¼	1½	8	6

Track Tanks.

Where express engines make long runs without stopping, means must be provided for supplying the tender with water, and for this purpose track tanks are used, being shallow tanks laid upon the ties, between the rails, while water "scoops" are fitted to the tenders. This arrangement was invented in England by Mr. J. Ramsbottom, in 1861. A vertical pipe with its upper end terminating in an elbow is placed in the tender tank, and its lower end extends through the bottom of the tank down nearly to the track, being fitted with an adjustable hinged "scoop," which is lowered about 3 ins. when the engine is passing over the tank, the speed of the engine forcing the water up the pipe into the tender. Water can be taken at a speed of 45 miles per hour. The scoop is operated by the fireman by means of a lever. These tanks are supplied by direct pumping or from ordinary elevated water tanks, the arrangement to be adopted depending upon the location of the station.

The track tanks put in by the Michigan Central Ry. on its Canada Southern Division, in 1893, are shown in Fig. 127. They are about 1,400 ft. long, of 3-16-in. steel, with a half-round 1½-in. stiffening bar along the upper edges,

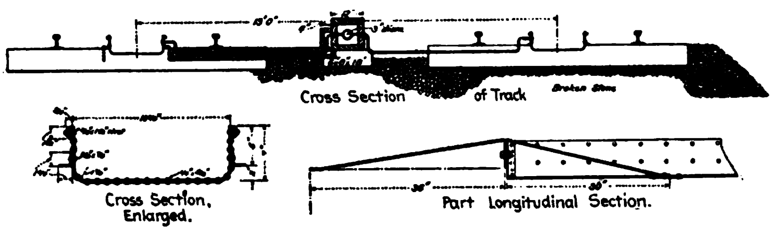


Fig. 127.—Track Tanks; Michigan Central Ry.

and an angle iron 1¾x1¾x3-16 ins. to support them on the ties, which are 8x8 ins., 8 ft. long, boxed out to fit the bottom of the tank. The half-round and angle irons break joints with each other and with the tank plates, and are butt-jointed. The plate rivets are ¼-in. diameter and ⅝-in. long; the others are ⅜-in. diameter; 1½-ins. long for the bars and ⅞-in. long for the angle irons. Water is supplied by a pipe entering at the most convenient point through a box riveted to the bottom of the tank, from which it flows through a 5-in. orifice into the tank. Branch pipes to admit steam to prevent freezing in winter are placed about 40 ft. apart along the entire length of the tank, and the construction of the ½-in. brass nozzle is such as to throw the jet of steam downward.

With very cold weather, however, steam jets are not sufficient to prevent the formation of ice, and on the Chicago, Milwaukee & St. Paul Ry. a circulating system has been introduced. At the mid length of the tank a 5-in. pipe enters the bottom, and forms the suction pipe of a steam pump. From the pump the water is forced into an 8-in. return pipe, into which is led a 1-in. steam pipe from the boiler. From the end of the return pipe two 3-in. pipes are laid parallel with and leading to each end of the tank, the water being discharged behind the inclined iron apron which raises the scoop in leaving the tank if the fireman has not raised it in time. The pipes are all laid in square boxes of 2-in. plank. This combination of

heating and circulation has proved successful at temperatures of 20° below zero.

The Baltimore & Ohio Ry., in 1890, adopted a very fast schedule between Philadelphia and Baltimore (1 hour and 47 minutes for 92 miles, with heavy trains), and two track tanks were put in, dividing the distance into three parts of about 30 miles each. The work has been described as follows by Mr. Andrews, of the Baltimore & Ohio Ry.:

The first work to be done was preparing the track at points where the tanks were to be placed. The troughs being 1,200 ft. long, it was necessary that the track for that distance be level, running off easily at each end to regular grade. This work was done by the regular track force. At Station No. 1 to get this level, it was necessary to raise at one end, the lower end being 17 ins. lower than the other. This required a double track through truss bridge of 115-ft. span, to be raised 17 ins. Station No. 2 was placed on a fill, where the grades formed a dip of about 4 ft., the grades being about 10.56 ft. to the mile, or 0.2%. The grade having been leveled, the hewed ties were replaced with sawed ties of white oak, 8 x 9 ins. These were boxed 1½ x 19 ins., at the middle, to form a seat for the troughs. The troughs were of 3-16-in. steel sheets, 15 ft. long. They were 6 ins. deep, 19 ins. wide, with an angle iron 1½ x 1¼ ins., riveted to each side, 1½ ins. from the bottom. These rest directly upon the top of the ties and the troughs are fastened to the ties by ordinary track spikes, the heads of which catch on the angle iron. This method of fastening allows the troughs to expand or contract. The troughs are fastened firmly at the centers, so that they will be stationary at that point, allowing for expansion at the ends. The troughs were made in 30-ft. sections in the shop. In laying them each joint was red-leaded, and cold riveted with 7-10-in. rivets, 20 to the joint. At each end is placed an inclined plane, with a total length of 13 ft. 8 ins.; the inner end of this is riveted to the bottom of the trough and the outer end fastened to the timber by means of rail spikes driven on the edge of the plate, with heads of spikes resting thereon, thus allowing for expansion of the trough. The object of this plane is to force the scoop on the tender of the locomotive up into position should the fireman fail to raise it, thus preventing any damage to either the scoop or trough.

At Station No. 1 it was necessary to construct a dam 6 ft. high and about 75 ft. wide across the stream at that point. From this the water is drawn through a 6-in. cast-iron pipe a distance of 600 ft. by means of a steam pump, and forced into a tank of 40,000 gallons capacity, placed 28 ft. above the track. At Station No. 2 the supply is received from a mill race about 600 ft. from the pump house. From this the water flows by gravity to a filtering well at the pump house and from this it is forced by a steam pump into a tank of 30,000 gallons capacity, 28 ft. above the track. These tanks are circular, with hexagonal roofs, covered with slate. The staves and bottom are of 3-in. white pine, the whole bound with 11 hoops of iron 3-16 x 4 ins. These tanks are always kept full, and from them the water is delivered to the track troughs in the following manner: An 8-in. cast-iron pipe is connected to the elevated tanks, and run to a point at or near the pump, where it is reduced to 6 ins. At this point is placed a 6-in. gate valve. The supply pipe, running direct to the trough, branches off to three points by means of tees, reduced at the point of leaving the valve to 3½ ins. Two of the branches are connected to the troughs at points 200 ft.

from the ends, and the third is connected to the center of the trough. At the points of connection of the water-pipe to the trough there is built a pit the full width of the track, about 3 ft. wide and 3 ft. 6 ins. deep, with the side and end walls of masonry; the top is covered with 2-in. plank, and the bottom drained to one side. Into these pits the pipe is run, and it is connected to the trough by means of a 3½-in. pipe flange, nipple and metal expansion joint. These expansion joints have been very satisfactory. Some Eastern roads have used a rubber hose in place of an expansion joint. At this point is placed a 3½-in. globe valve for use in emptying the troughs for cleaning or repairing.

One of the most important questions to be dealt with in the use of these tanks,is that of keeping them free from ice during cold weather. To do this a 2½-in. pipe is connected to the steam dome on the boiler in the pumping station, whence it is carried to the center of the tracks on double track, or to the ends of the ties on single track. There the pipe is reduced to 2 ins., and run to a point 5 ft. from the end of the trough. On this pipe at intervals of 45 ft. is placed a cross, from which a 1-in. pipe is carried to the troughs. This connection is made with a nipple of extra strong pipe, cut 3 ins. long, tapped out at one end and plugged with a ⅛-in. hole inclined downward. Immediately back of this nipple is placed a 1-in. check valve to prevent the back flow of water when steam is turned off. The 2-in. pipe in the center is drained from both ends with a drain cock placed at the lowest point. To prevent breakage through expansion or contraction, expansion joints were placed at intervals of 200 ft. All steam pipe should be boxed in and packed with mineral wool or covered with magnesia or asbestos pipe covering, to reduce the condensation. The pressure of steam necessary to prevent freezing in the coldest weather was found to be about 80 lbs. During the warm months, when steam is needed for pumping only, an upright boiler of 25 HP. is used. During cold months, when it is necessary to have live steam constantly in the troughs, an old locomotive boiler of about 80 HP. is used at each station. Each is, of course, connected to both its boilers. At these, as well as at all other water stations on the Philadelphia Division, a No. 9 Blake pump is used, with a capacity of 260 gallons per minute.

At the end of a trough nearest the approaching train is placed a signal similar to a high switch stand. This is to notify enginemen and firemen where to lower the scoop. At 100 ft. from the far end is placed a similar signal, at which point the fireman is supposed to raise the scoop, providing he has not filled his tank before reaching that point. As already mentioned, a 6-in. valve was placed in connection with the supply pipe at or near the pump house. Over these valves is built a small valve house, with its floor about on a level with the track. After an engine has taken water these valves are opened and water is allowed to run into the trough for from four to six minutes. When these tanks were first put in use there was considerable complaint that the troughs were often not more than two-thirds full. On investigation it was found that freight trains running over the trough had thrown out considerable water by the current of air caused by the passage of the cars. The pumpmen were therefore instructed to inspect the troughs five minutes before schedule time of trains; to see that they were properly filled: and to remain in the valve house from that time until after the train passed. The cost, complete, of the tanks was as follows:

	No. 1.	No. 2.
Preparing roadbed	$1,094	$2,767
Labor (placing trough, running pipe, etc.)	2,135	1,549
Trough (including all shop work)	4,159	4,159
Hauling	61	30
Material (including ties, pipe fitting, pipe)	2,939	3,030
Total	$10,388	$11,535

Labor includes all labor in the field except grading. Included in the above cost for No. 1 is the running of about 75 ft. of 8-in. cast-iron pipe and placing two stand-pipes for the use of freight engines. Included in the cost for No. 2 is the running of 600 ft. of 8-in. cast-iron pipe and the placing of two stand-pipes for use of freight engines. The following is the cost of operating each station per month:

Two pumpers, $45 each	$90.00
Coal, per month, 15 tons (average)	22.50
Ordinary repairs	20.00
Total	$132.50

Coaling Stations.

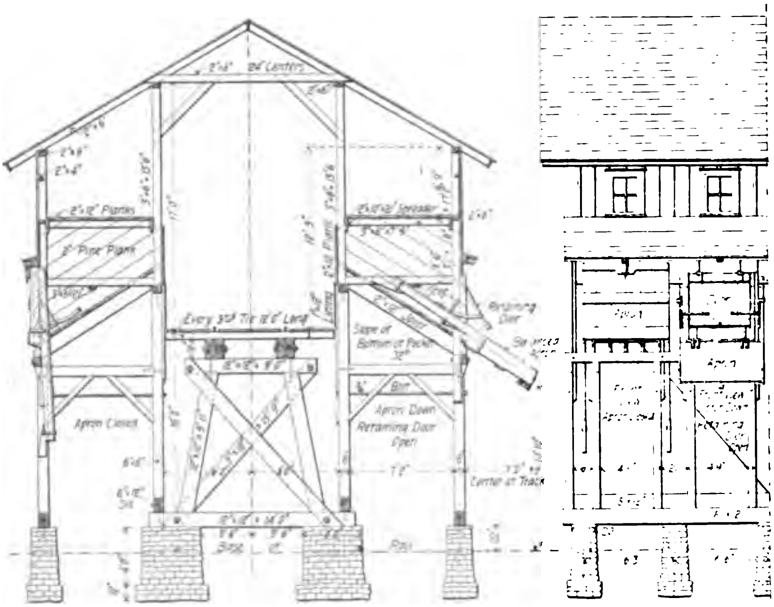
Coal may be loaded onto the engine tenders in various ways, according to the location, the topography, the number of engines to be supplied, and the ideas of the officers in charge of the establishment of these stations, but in any case the structures, apparatus and tracks are usually more or less under the care of the track department. In putting in any new plant for this purpose it should be borne in mind that the coal should be handled as little as possible and given as little of a direct drop as possible, so as to avoid breakage of the coal and the expenses due to rehandling.

The coal may be delivered into the tender by either one of four principal methods: 1, by hand shoveling from a coal stage; 2, by buckets handled by a crane on the ground or on a coaling stage; 3, by dump cars running on a coaling stage alongside the track; or, 4, by elevated chutes. These general plans admit of various combinations and modifications. The coal may be shoveled from gondola cars or dropped from hopper bottom cars onto the storage space on the ground or at the back of the coaling platform, and then either shoveled directly into the tender, or into buckets or cars which are wheeled to the crane or to the dumping track on the edge of the platform. For an important station the coal is usually stored in piles or bins and removed as required to the loading tracks by various forms of mechanical conveyors. On elevated or suburban lines using tank engines with small bunkers, a drop-bottom bucket is sometimes used, swung on the end of an arm operated by power; the bucket is not opened until it is right over the bunker, so as to avoid dust and waste.

The coaling station of the Pittsburg, Cincinnati, Chicago & St. Louis Ry., at Chicago, has a coaling stage or trestle 130 ft. long, with 16 ft. of straight track for unloading. The dump cars, which are of 5,000 lbs. capacity, are 5 ft. long, 8 ft. 10 ins. wide and 2 ft. 4 ins. deep, the back being over the inner wheels and the front projecting over the edge of the trestle. The body is pivoted over the sill nearest the edge of the trestle, and is held by a hook or latch at each end, while a rod under the body operates an iron apron which is lowered automatically as the car tips. This directs the coal properly into the tender, and avoids the use of fixed chutes or aprons on the platform. The cars are run from the loading place to an elevator at one end of the platform (on which they are weighed automatically while ascending), then pushed by hand to the point where they are to

be discharged, and then onto another elevator by which they are lowered to the ground, where a down-grade track carries them automatically to the loading place.

Where coaling chutes are used, they may be on a bridge over several tracks or in the side of a trestle parallel with a single coaling track. In some cases small cars are wheeled by hand from the coal pile and dumped at the chutes, but the better and more common plan is to have bins or coal pockets behind the chutes. These pockets may be filled directly from coal cars run into the coaling trestle (up an approach grade of 5 or 6%), but at large stations they are usually filled from the storage piles or bins by tubs running on a cableway or by a conveyor consisting of an endless chain with blades or scrapers running in a trough. Transverse troughs



Cross Section. Part Side Elevation.

Fig. 128.—Coaling Station.

fitted with gates control the discharge into the various pockets. These pockets may have a capacity of 3 to 5 tons each, and should be charged with different quantities so as to deliver any desired quantity to the engine.

In Fig. 128 is shown the construction of a coaling station fitted with the Burnett & Clifton chutes, a number of which have been erected by Williams & White, of Moline, Ill. The floor of the pocket is covered with No. 12 sheet steel and is at an angle of about 35° with the horizontal for bituminous coal, while anthracite will slide on a somewhat flatter angle. The door which retains the coal in the pocket is of oak, and is latched or unlatched by the movement of the apron. This apron, which may be of wood or iron, serves to direct the stream of coal into the middle of the tender, and when not in use swings up to a vertical position, covering the door of the chute. The apron is pulled down by the fireman by means of a chain, and is bal-

anced by arms which extend to the rear and carry an iron balance whose weight slightly exceeds that of the chute, so as to return it automatically to position when all the coal has run out. This avoids the use of chains and pulleys for counterweights. In the construction of a system of pockets, strength, durability and reliability must be carefully looked after. The rough handling, and the dirt and dust are likely to cause any complicated mechanism to get out of order, but it is necessary to have the opening and closing effected easily and quickly.

Ashpits.

The most common arrangement for handling the ashes from engines in yards where the ashpans are cleaned is to run the engine over a brick-lined pit, dump the ashes, and then shovel them up onto the ground and then into cars to be hauled away. In some cases small cars or buckets run on a narrow gage track in the pit, and are handled by a crane, the cars receiving the ashes as they drop from the engine. The shoveling of ashes is unpleasant and expensive work, and should be reduced as much as possible. This may be effected if the engine track is raised so that the ashes will be dumped on the ground level, or if the cinder car track can be depressed so that the floor of the pit will be somewhat higher than the sides of the cars. In either case the ashes will merely have to be shoveled to the side instead of being lifted. One side of such a pit can be left open and the floor inclined, so that the ashes can be shoveled readily into the

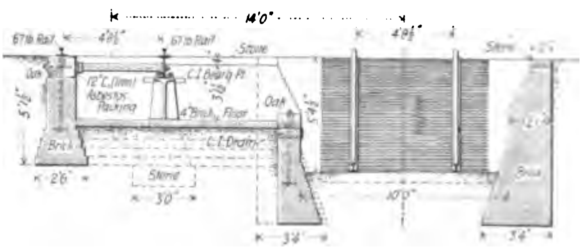


Fig. 129.—Ashpit; Illinois Central Ry.

car; or iron chutes may be provided, down which the cinders will fall direct from the engine to the car, a water jet being used to wash down the heavier parts, while the water jet will often move the ashes quicker and cheaper than shoveling. Conveyors may also be used where space is limited and the ashes from a large number of engines have to be handled. A long and comprehensive report on this subject is given in the report of the 1894 meeting of the American Association of Railway Superintendents of Bridges and Buildings.

With narrow pits the rails may rest on wooden stringers on the side walls. With wider pits they may be carried on wooden or iron stringers resting on iron columns or brick piers. Two 15-in. I-beams, under each rail, bolted together and connected by tie-rods, make a substantial support for the track, the span being about 15 to 20 ft. The rails may be attached by bolts, or keyed in iron chairs; while oak packing blocks between the beams and their supports make the track somewhat elastic, and enable the level to be adjusted. The ironwork, brick walls (of narrow pits) and piers, and wooden stringers, should be protected from contact with hot ashes by sheet-iron coverings.

The pit at the shops of the Illinois Central Ry. at Burnside, Ill., Fig. 129, is 80 ft. long. It has the outer rail carried on a 12 × 16-in. oak timber on the side wall, protected by a 12-in. iron channel with asbestos packing; and the inner rail is carried on a line of 12-in. I-beams supported by cast-iron pedestals 10 ft. apart. These beams are bolted through to the timbers by 1¼-in. wrought iron rods, with 4½-in. wrought iron sleeves. The floor is of 4-in. firebrick and has an oak fender 8 × 13 ins. The pit is 3 ft. 5½ ins. deep below rail base, and its floor is 2 ft. 4½ ins. above the base of rail of the depressed cinder track. A line of metal pipe is laid on each side of the pit and provided with cocks to supply water for cooling the cinders and washing the pit. The Chicago, Milwaukee & St. Paul Ry. uses a single line of I-beams resting on cast-iron yokes or pedestals about 3 ft. 8 ins. high, set 15 ins. in the ground, the lower part of the two pedestals being connected by a transverse web of inverted T section 12 ins. deep. The pedestals are 6 ins. square, 20 ins. on the bottom. These yokes are 8 ft. 10 ins. apart, c. to c., and the I-beam stringers are connected over each yoke by a tie-rod with 1½-in. gaspipe spacing sleeve. The pit is 62 ft. long, 14 ft. wide, 3 ft. 3 ins. deep below base of rail on one side, and 3 ft. 5 ins. on the other, with a drain on the lower side. An open-side pit on the Chicago & Northwestern Ry. has one rail carried on the edge of the side wall and the other on a single line of 15-in. I-beams, resting on iron posts 2 ft. high and 6 ft. 8 ins. apart. c. to c. At each support is a transverse 12½-in. I-beam, with one end riveted to the 15-in. beam, and the other end built into the side wall, which is 18 ins. thick on the top and 24 ins. on the bottom. The pit is 40 ft. long, with a flagged floor 14 ft. 6 ins. wide from the wall to the edge of the platform. Alongside the platform (and below it) is the ash track, depressed below grade so as to bring the cars at convenient level for shoveling. Shallow pits, 16 to 20 ins. deep, with rails on longitudinals, and having an iron lining for the bottom and sides, are sometimes used, particularly on elevated railways.

Turntables and Transfer-Tables.

Wooden turntables with deep trusses, or with heavy beams having the ends supported by guy rods from a gallows frame or framed tower at the center of the table, are still in use, but few such tables are now built. They are rarely more than 50 ft. long, and of 50 tons capacity; some have the ends supported on wheels, while others swing entirely on the central bearing. Modern turntables usually have fish-bellied iron deck girders, either cast or built up; but through girders are occasionally used, and if a deep girder is required for a shallow pit a half-through arrangement may be used. These tables are often designed for engine and tender loads of 120 to 175 tons, and require to be turned with reasonable ease by one or two men bearing against levers at each end, though gearing operated by crank handles is sometimes employed.

Turntables are of two general types: 1. Those which have a center bearing and a rim bearing of wheels running on a circular track at the circumference of the pit; 2. Those which swing entirely from the center. In the former case, coned wheels or rollers under each end are used for the rim bearing, running on a circular track of T-rails or flat rails on the masonry of the pit wall. In the latter case, one of the best arrangements has a fixed central pedestal, with the weight of the table borne by a cap bearing

level with the deck, while vertical guide rollers bearing against the base of the pedestal serve to steady the table. A 66-ft. turntable of this kind, with a capacity of 120 tons, has four cast-iron girders, each pair coupled together at the deeper ends by heavy forged bars, forming two fish-belly girders 4 ft. deep at the middle. The weight is supported by 16 small conical steel rollers in the cap bearing, and guide rollers are also provided, as noted above. A table of this kind will tip and lock in line and surface to receive the load, unlock when the engine is completely on the table, balance to a horizontal plane with the load, tip and lock for the locomotive to run off, and then unlock and return to a horizontal position. All new turntables should be made long enough and strong enough to take the largest and heaviest engines on the road; and should be well braced and balanced to swing true, easily and steadily. The bearings, wheels and tracks should be carefully looked after, more especially in roundhouse tables, as any failure of such a table may tie up all the engines in the stalls.

The pit may have a dished bottom, paved with brick, and having the circular track carried by wooden blocks, but the more common plan is to have a flat bottom and to form the masonry of the wall in a step or bench at the bottom to carry the circular track. The masonry should be well built, and the pivot foundations and track bearings kept true and substantial. Proper drainage should be provided, and the pit kept free from weeds and refuse. It is usually open, but sometimes covered by a circular platform carried by the turntable; this is not a good plan, however, as the pit is more likely to be damp and dirty if thus covered. An English 55-ft. deck plate girder turntable, with curved top chords, has a pit 4 ft. 6 ins. deep (below the rail), and only 12 ft. diameter. Each end of each girder has a coned wheel running on a circular surface track, and the table swings on the cap bearing in the top of the pedestal. A comprehensive article on railway turntables was published in "Engineering News," New York, in March, 1897.

A transfer table, connecting a series of parallel tracks, runs on a straight track in a pit at right angles to these tracks, and is supported on several pairs of wheels running on T-rails, spiked to short blocks or ties, the rails being usually 10 to 12 ft. apart. A 70-ft. transfer table of 70 tons capacity on the Union Pacific Ry. has nine sets of 36-in. wheels with flat chilled treads. Each pair of wheels is carried between a pair of I-beams forming one of the transverse girders of the table. These beams extend beyond the table and carry the wheel bearings on top, so as to keep the pit as shallow as possible. The entire framework is thus suspended from the 18 bearings. If power equipment is used, some of the transverse girders are made sufficiently long to carry a platform for the operating machinery, which is enclosed in a house for the operator. In the table above mentioned, the nine wheels on one side are attached to a single shaft (made in sections connected by couplings) and this is driven by gearing by an electric motor of 15 HP. (220 volts), or in some tables a 25 HP. motor is used. A trolley line supplies the current from the power house. This table, with a travel of 300 ft. will run at 90 ft. per minute with full load, or 250 ft. per minute with light load, the speed being controlled by a friction brake. The full power is not required for moving the table, but for hauling cars on and off the table by means of a capstan, the speed of the hauling attachment being 90 ft. per minute. Steam power is sometimes used.

At the shops of the Illinois Central Ry. at Burnside, Ill., there is a transfer table 80 ft. wide running in a pit 426 ft. long, having five tracks 17 ft. 7½ ins. c. to c. The depth is 13 ins. from base of track rail to head of pit track rail. The walls are of Portland cement concrete 16 ins. thick, with a natural cement concrete base widening out to 3 ft. wide, and capped by a yellow pine timber 8 x 16 ins., laid flat, and secured by bolts having anchor plates in the concrete. The height from base of wall to top of timber is 5 ft. The table proper consists of an iron frame mounted on trucks and carrying the flooring and operator's cabin. It is operated by a Gibbs' electric motor, current being taken from an overhead trolley wire.

Track Scales.

The pits for track scales should have side walls of concrete, brick or stone, built on a foundation of piling or concrete, and should be well drained. The piling should be cut off below ground and covered with a concrete floor, 24 to 36 ins. thick, graded and guttered for drainage. Rubble masonry walls are not to be recommended. In some cases piles are driven along the sides of the pit and capped with timbers which form the curb or coping, while sheathing planks are placed behind the piles to form the sides of the pit. Similar piles also support the stringers for the dead rails. The straight track across the pit has the rails supported by stringers so that cars running on this track do not bring the scales into action. The weighing track is gantleted with the straight track, its rails being about 10 or 12 ins. from the siding rails. A rail length of straight track extends from the weigh track on each side of the scale table, and then another rail length connects the weigh track with the straight sidetrack. The scale tables are usually 30, 36 or 42 ft. long, with a capacity of 60, 80 or even 100 tons. With the growth of the system of making up freight trains by the actual loaded weight of cars, a greater number of track scales will be needed.

Bridge Tell-Tales or Ticklers.

On nearly every railway there are many low overhead bridges which are a constant source of danger to freight train brakemen, whose duties call them on top of the cars to set the hand brakes. The increasing use of power brakes on freight trains is gradually diminishing the necessity for such work, and low bridges are in some cases being raised, but in the meantime the warnings against these dangers must be provided. The New Hampshire laws of 1893 require a minimum clear headway of 21 ft. from the rail for all new bridges, and a maximum height for freight cars of 14 ft. from rail to top of running board. Where low bridges are carried over the railway, men on the cars must be warned to lie down, but sometimes as at shallow cuts, with a headway of perhaps only 15 ft., there is not room for a man even to crouch on top of a box car of maximum height (such as a furniture car), and if he is not warned in time to reach the end of the car and step down between the cars he is almost certain to be killed or injured. This is specially the case with men who are not familiar with the road, but even those who are thus familiar cannot always judge of the position of the train at night or during a storm.

A tell-tale or "tickler" is used to give warning of the approach to an overhead bridge with less than 18 ft. clear headway, and one of these is usually placed on each side of the bridge, about 150 ft. from it, so that the

men will have time to stoop or lie down. The apparatus usually consists of a gallows frame with single or double post, having a row of ropes, leather thongs or flat tempered steel ribbons, about 30 ins. long, hung from the cross arm over the track, and reaching 3 to 6 ins. below the level of the lowest part of the bridge. When ropes get wet or frozen they will strike quite severe blows, and in this respect the leather thongs or straps are better, but, unfortunately the brakemen have a propensity for cutting off the thongs for personal use. They also have a propensity for showing their dexterity by catching the ropes or thongs and throwing them up as the train passes, so as to twist them around the crossarm, and thus the brakeman on another train may be killed for lack of the warning. To prevent this, as well as to prevent the wind from blowing the ropes up over the

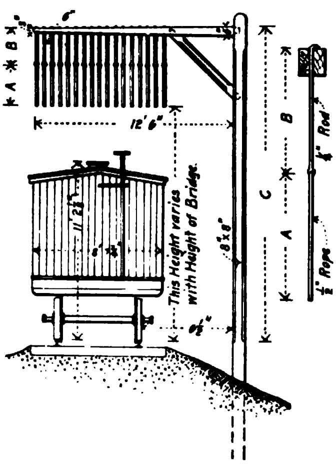


Fig. 130.—Bridge Tell Tale; Pennsylvania Lines.

arm, the ropes or thongs may be attached to a bar suspended by links from the cross arm, or each rope may be attached to the eye of a 1¼-in. rod, the upper end of the rod passing through the cross arm and being secured by a nut, or by being bent over. This latter arrangement is shown in Fig. 130, which is the bridge alarm used on the Pennsylvania Lines at all bridges and structures less than 19 ft. 6 ins. clear above the top of the rail. The timber is of white pine, the post being tarred below the ground line. The bottom of the ropes must be at least as low as the lowest point of the bridge, and the requisite dimensions are given in Table No. 13:

TABLE NO. 13.—BRIDGE TELL-TALES; PENNSYLVANIA LINES.

	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.
Clear headway	15 6	16 0	16 6	17 0	17 6	18 0	18 6	19 0	19 6
Length of rope (A)...	4 1	3 7	3 1	2 7	2 3	2 3	2 0	2 0	2 0
Length of rod (B)....	3 5	2 11	2 8	2 5	2 2	1 11	1 11	1 11	1 11
Height from rail (C).	23 0	22 6	22 3	1 10	21 9	21 6	21 6	21 6	21 6

The Cincinnati Southern Ry. uses a somewhat unusual form, having a wire screen 8 ft. wide and 2 ft. 8 ins. deep, made of No. 10 wire, with a 1-in. mesh, and having a rim of ½-in. rod. This screen is supported by three ½-in. eyebolts with the nuts on top of the cross arm. Leather thongs were attached to the lower edge, but as these were cut off by trainmen

they were replaced by double-braided ½-in. cotton ropes, well knotted to the screen, and having the ends bound to prevent raveling. These ropes are 2 ft. 8 ins. long, 6 ins. apart, with the lower ends 16 ft. 10 ins. above the tops of the ties. A double post frame is used, with posts 8 × 8 ins., let into sills 8 × 8 ins., parallel with the tracks, and having foot braces 6 × 6 ins. The crossarm is 4 × 8 ins., braced by four pieces 3 × 6 ins., 10 ft. long, boxed out 1 in. over the posts and arm, and all secured by ⅝-in. bolts, 9½ ins. long for the arm and 13½ ins. long for the posts. The clear width between the posts is 20 ft. Where there are several tracks to be guarded, as at yards, the ropes or thongs may be hung from a ⅞-in. wire cable stretched across the tracks, but care must be taken to brace the posts well on the track side, and to provide means for taking up the slack of the rope, or the cable may sag so much as to strike a man and throw him from the train. The posts may extend above the point of attachment of the cable, and have suspension or stay cables from the top of the post to support the middle portion of the main cable.

A different type of tell-tale consists of a light pivoted horizontal rod about 1¼ ins. diameter, projecting across the track at proper height. The heel is so attached to the post by a swivel that when the rod is struck it swings easily round parallel to the track, a light suspended weight bringing it back to its original position. In the Walling tell-tale the rod is attached to a shaft inclined at an angle of 45° from the horizontal, and this shaft is carried by a swivel on the post so that it is free to swing at an angle of 45° from the vertical. When struck, the rod swings backward and upward, and the action of gravity returns it to and keeps it at its normal position.

Mail Cranes.

These are the fixed stands to which are hung the bags to be snatched off by the "catcher" on the passing mail car. In 1893, when a count was made, there were about 8,700 post offices supplied by cranes and catchers. The cranes are of different designs, but are almost all alike in general principle, consisting of a vertical post with two hinged horizontal arms, one above the other, to which are attached the top and bottom of the mail bag, which is thus prevented from swinging. These arms extend towards the track, and when not in use lie vertically against the post, so as to be out of the way. On four-track lines where the two middle tracks are the passenger tracks, the ordinary crane cannot be used. The Pennsylvania Ry. uses a crane with a long swinging arm to reach across the intervening track, but a better device is the iron crane used by the New York Central Ry., which is set between the tracks, and has the upper part turned parallel with the tracks when not in use. This crane is shown in Fig. 131, together with the gage for erecting it at its proper position in relation to the catcher on the mail car. The stand should be carried on the ends of two long ties, so that any alteration of level of the track by surfacing, heaving, etc., will not affect the relative position of the crane to the car.

Wooden mail cranes are generally used, and the standard form on the Louisville & Nashville Ry. is also shown in Fig. 131, being very similar to the form recommended by the Railway Mail Service Bureau of the Post Office Department. The arms are shown in position for the bag, but when it is taken off they swing to a vertical position, the upper one against the back and the lower one against the front of the post. A small rubber block on the arm or post will prevent jarring when the arms fall. The iron tongues

over which pass the straps of the bag have no spring to hold the straps, a slight groove in the irons and the tension on the straps, due to the arms, affording ample security. In the Post Office style of crane the iron tongue is straight and flat, with a light spring of curved steel fitted above the end

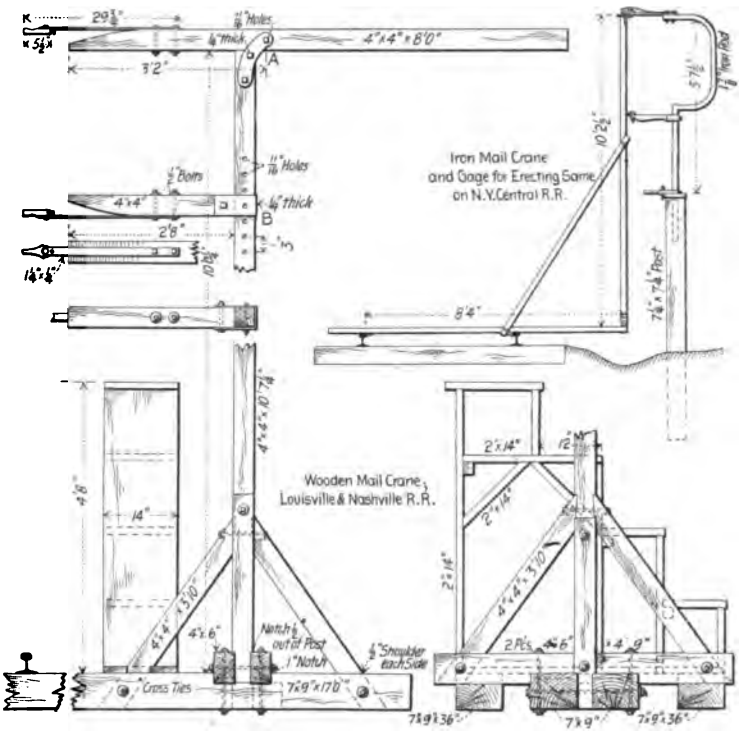


Fig. 131.—Mail Cranes.

of the upper arm and below the end of the lower arm. Sometimes the lower part of the post is enclosed in a box filled with stone, the steps forming a part of the box. The bill of material for the wooden crane shown in Fig. 131, is given in Table No. 14:

TABLE NO. 14.—BILL OF MATERIAL FOR MAIL CRANE.

	ins. ins. ft.		ins. ins. ft.
1 vertical post	4 × 4 × 11.0	2 cross ties	7 × 9 × 17
1 upper arm	4 × 4 × 8.0	2 blocking pieces	7 × 9 × 3
1 lower arm	4 × 4 × 2.9	2 step boards	2 × 14 × 12
4 braces	4 × 4 × 4.0	1 " "	2 × 12 × 7
2 cross pieces	4 × 6 × 4.9	1 " "	2 × 5 × 5
2 steel spring straps.		1 strap for lower arm (B).	
2 straps (curved) at top vertical post (A).		30 cast washers for 1½-in. bolts.	

8 bolts 1⅛ ins. diameter, through post and arms, 5¼ ins. under head.
2 bolts 1⅛ ins. diameter, through post and braces, 9½ " " "
7 bolts 1⅛ ins. diameter, through cross pieces, 13 " " "
3 bolts 1⅛ ins. diameter, through cross ties,.... 23 " " "
1 movable pin for lower arm, ⅛ × 5 ins.

The present standard height of crane is objectionable in that it brings the upper arm (when carrying a bag) so high and so near the engine cab window that enginemen are frequently struck when looking out of the win-

dow. It would be well if the height could be slightly lowered, the catching bar on the mail car door being correspondingly lowered.

In the Flemming mail crane, used on the Erie & Pittsburg Ry., the bag is slung by a short chain around its middle from a large ring, this ring being attached to the ends of two iron arms parallel with the track, on the ends of the wooden arms. The catcher arm on the car enters the ring and picks off the bag, while a catcher arm on the crane picks off the bag hung from the car to be delivered at the crane. The arms and bag are further from the car than in the ordinary arrangement.

Bumping Posts.

At the ends of tracks in yards and stations, bumpers or bumping posts are erected to prevent cars from running off the end of the track onto the ground or across the platform. A pile of old ties is often used for this purpose, but is unsightly and of little use. To bend up the ends of the rails vertically for about 12 ins., and to place a heavy timber across the ends, is little if any improvement, as cars kicked back with any force will easily jump the low bumper and pull the track endways, while there is liability of stripping the truck from the body and damaging the brake rigging. One form of low bumper for yard use, which is not very likely

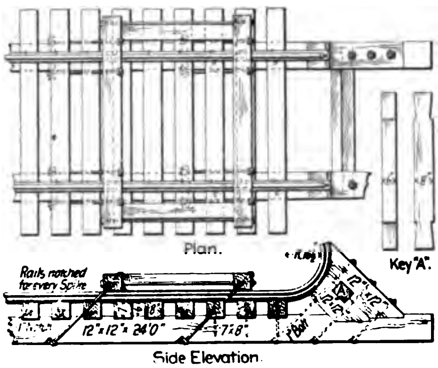


Fig. 132.—Low Bumping Post; Pennsylvania Lines.

to be jumped, is shown in Fig. 132, and is used on the Pennsylvania Lines West of Pittsburg. Double blocks, with horizontal springs between them are sometimes used, but in general a high bumper which will catch the car frame is better. A bank of earth or cinders makes a good stop at the end of a yard track, and may be used as a backing for a high bumper; a plank sheathing behind the bumper sustaining a vertical face for the bank.

The simplest form of high bumper consists of three heavy timbers; a sill, a vertical post and a back brace, all mortised and strapped together, the sill being buried in the earth. A step in advance consists of two such frames, with one or more horizontal timbers or deadwoods to take the blow of the car coupler or platform, and having an inclined tie-rod to the track end of the sill. The bumper of the Louisville & Nashville Ry., shown in Fig. 133, is of this type. The sills are 12 × 12 ins., 18 ft. long, with bolted cross pieces 10 × 10 ins. above and below. The posts, braces and deadwoods are all 12 × 12 ins., and the tie-rods are 1¼ ins. diameter. The bottoms of the sills are 4 ft. below base of rail, and the tops of the posts 5 ft.

8½ ins. above the base of the rail. The deadwoods are faced by a ¼-in. iron plate 34 x 36 ins. With dressed faces and chamfered edges, the frame has a neat and strong appearance for passenger stations, and the number of the track may be painted on both faces of the tops of the posts. The rails rest upon stringers or upper sills 12 x 12 ins., the ends of which are supported by the 8 ft. cross timbers, 8 x 8 ins. section, bolted to the posts. An elaborated bumper of this same type is used at the ends of tracks on a slight down grade in the Cincinnati freight station, where there is a platform right behind the bumpers. In this latter design the sills are 14 x 14 ins., 50 ft. long, 4 ft. apart in the clear, with five transoms 6 x 14 ins. (framed 1 in. into the sills at each end), and 1-in. transverse tie-rods. The posts are 14 x 14 ins., 7 ft. 8 ins. high from the sills, and placed 10 ft. from the rear ends of the sills. The back braces are 12 x 14 ins., and the inclined tie-rods are 2 ins. diameter, with special beveled cast-iron washers to avoid cutting the posts. The deadwood is 12 x 18 ins., and in front of it

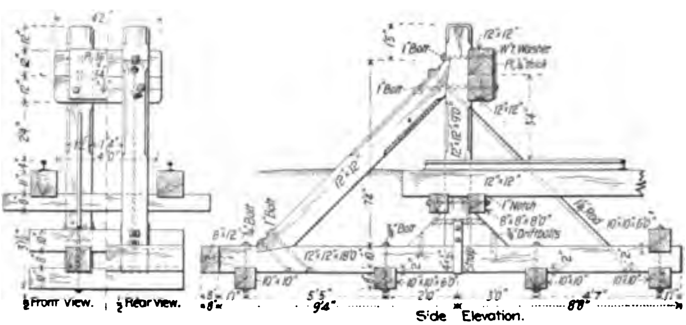


Fig. 133.—High Bumping Post; Louisville & Nashville Ry.

is a striking plate 8 x 8 ins., separated from it by six rubber blocks 6 ins. diameter and 5 ins. thick, with a 1-in. bolt through each. To the face of this latter timber are bolted two pieces 8 x 18 ins., 3 ft. 3 ins. and 2 ft. 2 ins. long, the front one being faced with a ¾-in. iron plate 18 x 26 ins. The track ties are laid directly upon the sills, the alternate ties being secured by ⅞-in. bolts.

The standard freight car bumper of the Pennsylvania Lines West of Pittsburg is very similar to that of the Louisville & Nashville Ry., Fig.133, but has sills 18 ft. long, with the center of the posts 14 ft. 8 ins. from the back end, while the cross pieces are 8 x 12 ins.,drift-bolted to the sills. No track stringers are used,the ends of the rails being supported by the 8 x 10-in. timbers bolted to the posts. The iron plate on the deadwood is ¾-in. thick, 34 x 44 ins. This bumper is very plain, with square unchamfered posts, and costs about $54. For bumpers on docks and wharves the sill should be the same depth as the track stringers, and the track in front of the bumper should be well anchored down, while a back brace may be put in between the bumping timber and one of the dock piles or a special pile.

For terminal tracks in passenger stations, low bumpers to catch the wheels of cars are often used, generally in pairs, with sets of steel car springs placed between them to take up the shock. It is more common, however, to use high bumpers, of the general type already described, but having the deadwood and striking timber separated by two or three pair

of heavy car springs. The Pennsylvania Ry. also sometimes uses vertical stirrup irons to keep the springs from deflecting vertically, the upper end of the stirrup being bolted to the striking timber and the lower forming a yoke to embrace the track rail. Where the sills are buried, the rails or ties may be laid upon upper sills carried by cross timbers mortised into the lower sills, secured by bolts passing through both sills. A useful addition to this style of bumper is a bottom deadwood for the car wheels to strike when the car platform strikes the upper deadwood. As the distance from front of wheel to front of platform varies, this lower timber may be a loose sliding timber placed in advance of the bumper frame. Frames of flaring Λ-shape, made of old rails, may be used in pairs to carry the bumping timbers of, or to act as braces for, high bumpers. The number of the track may be displayed on a board or sheet-iron target attached to the top of the bumper frame, for the information of trainmen and passengers.

The Ellis bumping post, which is extensively used for yards and wharf tracks, has a single post to which the deadwood and striking plate are attached. Two T-rails secured to the ends of the track rails by six-bolt angle bars are bent upward at an angle and also bent inward, so that they meet behind the post and deadwood, where they are bolted together and to a heavy casting supported by an oak block or post at the back of the bumper post. For passenger car tracks, a rubber cushioned striking plate is used to take the shock of the spring platform buffers of the car. This is made by George E. Chatfield, of Chicago.

Hydraulic buffer stops are used in some English passenger terminal stations, and Fig. 134 shows the arrangement designed by Mr. F. W. Webb and used by him on the London & Northwestern Ry. It consists essen-

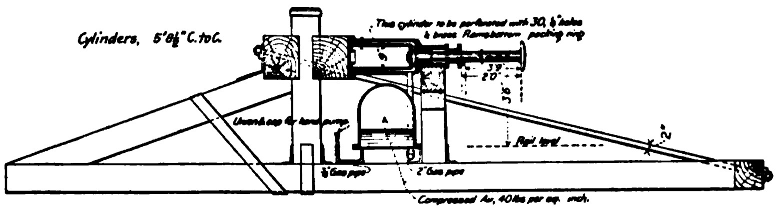


Fig. 134.—Hydraulic Buffer Stop; London & Northwestern Ry.

tially of two heavy frames of timber, but to the deadwood are attached two hydraulic cylinders, at the right distance apart for the buffer heads forged on the 4-in. piston rods to engage with the spring buffers on the end sills of the cars. The cylinder in which the piston works is 9 x 24 ins., and is perforated with 30 holes ¼-in. diameter, and is enclosed in another cylinder, with a space of about 2¼ ins. between them. The front end of the smaller cylinder is open. The cylinder is filled with liquid and as the piston is forced back when a train strikes the buffers the liquid is forced out through the small holes into a chamber containing air at 40 to 45 lbs. pressure. The resistance increases towards the end of the stroke, as the number of holes gets less. The liquid used is a mixture of petroleum, soap and water, ensuring good lubrication. The air chamber will retain the pressure for some months.

Terminals of elevated railways should be provided with specially strong bumpers, as in some cases runaway cars have broken the bumpers and

fallen into the street, but this danger seems to be generally lost sight of, and, as a rule, the bumpers are not of very substantial construction. They are generally similar to those used on steam railways, consisting essentially of two vertical posts carrying a horizontal striking timber, the posts being braced by timbers at the back and tied in front by rods to the structure. Some of the yielding portable bumpers, which skid the front wheels and then slide along the rails give good results in service. Whatever form is used, the principle of its design should be the gradual absorption of the energy of the train, and all the space that can be spared should be given up to it. Beyond these devices or service bumpers, should be a heavy timber bumper secured to the railway structure with fastenings designed to take the shock of a collision, and the track should incline sharply up to this, the bumper being built so that its face is perpendicular to the track on the incline. The best plan in any case, where room can be spared, is to make the track approaching the end of the structure on an ascending grade, which rapidly grows steeper toward the end, thus absorbing the energy of the train.

One form of the portable rolling stop-blocks above referred to is shown in Fig. 135. It consists of a pressed steel or iron tongue A, resting on the

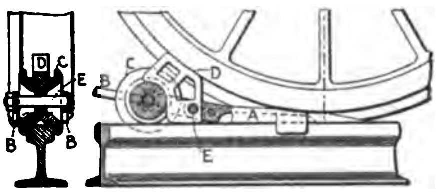


Fig. 135.—Rolling Stop Block.

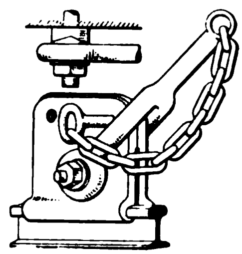


Fig. 136.—Portable Stop Block.

rail and connected by a loop or strap B, at its rear end with a small double flanged wheel, C, journaled in the sides of the strap. Between the wheel and the back of the tongue is a wrought-iron brakeshoe, D, pivoted to the strap at E, and resting on the rail and in a groove in the flat tread of the wheel. When a car wheel runs up on the tongue and strikes the block, this block is pressed hard against the wheel and rail, stopping the revolution of the car wheel, while the force of the blow carries the stop-block back along the rail until it comes gradually to rest, being held on the rail by the grooved wheel and by lugs on the tongue. This device is used in Germany. A useful form of portable stop-block for use in locking cars on yard or shop tracks is shown in Fig. 136, and may be fitted with a padlock. It is made by Thornton N. Motley & Co., of New York.

Spare Rails.

It is the usual custom, particularly on important railways, to place one or more spare rails at the side of the track at every mile post, ready for use in case of emergency. They are generally carried on three stakes, 6 x 12 or 3 x 8 ins., 3 ft. to 4 ft. long, with the top cut like a step to form a seat for the rail base, or notched to hold the head and web of an inverted rail. In some cases planks are driven in the ground, with their edges toward the track, and are notched to hold the rails, but the stakes make a much

better arrangement. They should be placed at the side of or in front of the mile post, set 12 ft. apart, with the inner face 7 ft. from the rail and the top about 18 ins. above subgrade. If special attention is paid to neatness and finish, the ground may be dressed off level and covered with cinders and gravel for a length of about 33 ft. Where conditions of light track and heavy traffic lead to somewhat frequent breakages of rails, or where the spare rails are more than a mile apart, it may be desirable to keep two or more rails at each place, in which case the tops of the stakes can be offset to give two seats 4 or 5 ins. wide, or the required number of notches may be cut in the plank supports.

Buildings.

While the construction, maintenance and repair of the principal buildings of a railway are beyond the province of the track department, yet many of the smaller buildings have to be looked after more or less by this department. These include section tool houses; cabins or shanties for switchmen, flagmen, and gatemen; signal towers; small stations and flag stations; and dwelling houses for foremen and section men. Such buildings are usually of frame construction, easily and cheaply built and kept in repair, and care should be taken that they are not allowed to get into a slovenly and dilapidated condition. The roofs may be of shingles, tin, corrugated iron or tarred roofing felt; while corrugated iron may be used also for the covering or paneling of small station buildings and gatemen's cabins, and for the covering of freight sheds. The material and style of construction will depend largely upon local conditions, the climate and the extent to which the officials allow for appearance. Particulars of buildings of various styles are given in the book on "Buildings and Structures of American Railway," by Walter G. Berg.

For painting frame buildings (of yellow pine) Mr. Samuel Wallis has recommended a priming coat as follows: 100 lbs. of pure white lead in oil, 4½ gallons of pure raw linseed oil, and 1 gallon of pure spirits of turpentine. This gives 8 gallons of paint ready for use, and should be allowed 48 to 60 hours for drying, or longer in damp weather. The second coat should never be applied until the priming is thoroughly dry. The second coat should be composed as follows: 100 lbs. of pure white lead tinted to shade with not more than 12 lbs. of tinting material, 5 gallons of raw linseed oil and 1 quart of good strong turpentine dryer. The third coat should consist of 5 gallons of pure kettle-boiled linseed oil to 100 lbs. of a paste composed of 60 lbs. of pure white lead, 30 lbs. of zinc white free from sulphides, and 10 to 12 lbs. of tinting material. For ironwork, the following is recommended: Priming coat; 100 lbs. of pure red lead to 5 gallons of pure raw linseed oil; Second and third coats (for black color); 20 gallons of pure kettle-boiled linseed oil to 100 lbs. of a paste composed of 65 lbs. of finely hydrated sulphate of lime, 30 lbs. of fine quality lampblack, and 5 lbs. of red lead. This makes 30 gallons of paint. If much painting is to be done, it is well to have it made from good raw materials purchased by the company; but for repairs and small jobs ready made paints of good quality may be used to advantage.

As to the color of the buildings under consideration, various shades and combinations of green, brown and yellow are common, according to the styles affected by different roads. A plain dark tuscan red is a serviceable and well wearing color, and may be relieved by a darker amber brown on belt-rails, posts, etc., if some attempt at a pleasing effect is permissible.

Two shades of heavy green also make a good combination, but the common, dull yellow ochre with dull red trimmings (which is used by several roads) is extremely ugly. The tool house in Fig. 137 is painted in two shades of greyish brown, one being of a very light shade. One of the most attractive and cheerful arrangements is the colonial buff or yellow with white trimmings, as adopted by the Chesapeake & Ohio Ry. for stations, cabins, etc. A little light paint on mouldings, etc., will lighten up almost any style of coloring.

The painting and whitewashing of buildings, fences, cattle pens, etc., can be quickly, conveniently and economically done by compressed air, on somewhat the same plan as that used for kalsomining the buildings of the Columbian Exposition, at Chicago, in 1893. Many roads are now using

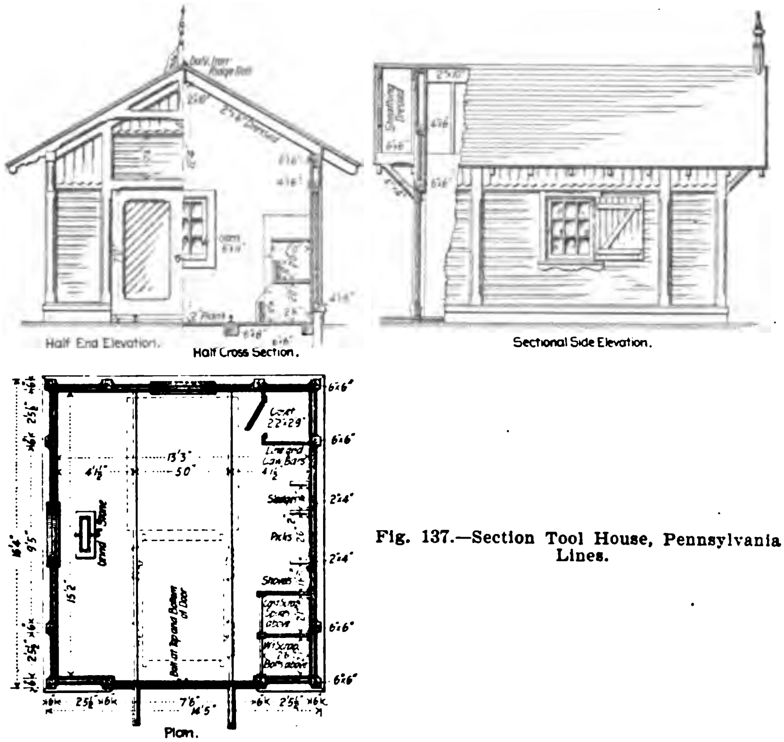


Fig. 137.—Section Tool House, Pennsylvania Lines.

this system with success for painting car repairs as well as buildings. In one case an old freight car has been fitted up with three air brake pumps and two reservoirs, the pumps being driven by steam from a locomotive, and a pressure of 40 lbs. being maintained in the reservoirs. Paint tanks are also mounted on the car. The painting nozzle consists of an iron tube with a funnel-shaped end, and to each nozzle are attached two lines of hose, one from the air reservoir, and the other from the paint tank. The flow of air induces a stream of paint or whitewash which is expelled in the form of spray, the flow being regulated by a valve on the nozzle. Paint must be mixed somewhat thinner than when it is to be applied with

a brush. The advantages of this method of working are the rapidity of the work, the saving in cost of brushes where rough or unplaned lumber has to be painted, and the general reduction in cost, while paint thus applied readily finds its way to joints and narrow spaces almost inaccessible by a brush. On some large roads there is a regular traveling paint gang, which is carried from place to place on special cars fitted up with living accommodations and the necessary appliances.

A good whitewash is described as follows: Slack half a bushel of unslacked lime with boiling water, keeping it covered; then strain it and add the following: 1 peck of salt dissolved in warm water, 3 lbs. of ground rice put in boiling water and boiled to a thin paste, ½ lb. of powdered Spanish whiting, 1 lb. of clear glue, dissolved in warm water. Mix the composition thoroughly and let it stand for several days. When wanted for use, heat it in a kettle or portable furnace and apply hot with brushes. The addition of 1 part commercial silicate of soda to 5 parts of whitewash, will make a fireproofing material for coating wood.

Section Tool Houses.—These vary very much in size and design, according to the requirements and to the ideas of the designers, but they should be large enough to hold the hand-car, tools, supplies, etc., and still leave room for the men to do such work as cutting shims, sharpening tools, sorting

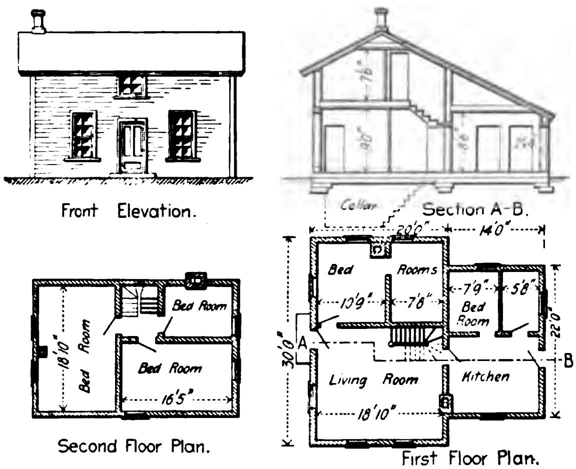
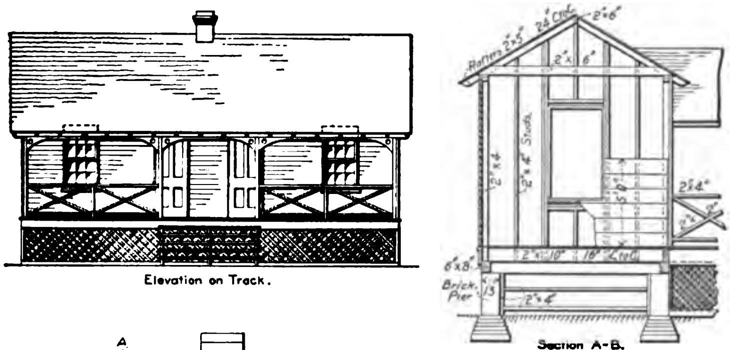


Fig. 138.—Section House; Canadian Pacific Ry.

scrap, etc., in wet weather. The building is generally oblong in plan, and if very small it should be placed with its longer side towards the track, with the hand-car track laid through one end of that side, so as to leave the other end of the building unobstructed for the men to work in, but with buildings 14 or 15 ft. wide the track may be in the middle. There should always be room for the car to stand between the house and the track.

One of the simplest and cheapest forms is about 9×12 ft., 7 ft. high, 10 ft. to the top of the pitched roof, and having double swing doors in the narrow gable end facing the track. The sills are 6×6 ins.; plates and rafters, 2×4 ins.; floor beams, 4×8 ins., 13 ft. long, spaced 27 ins. c. to c., and having

2-in. floor planks with hand-car rails, 2×3 ins. As a general thing, however, a larger and more convenient tool house than this is provided. Shelves, hooks and racks for tools should be fitted up to suit the equipment, and there should also be boxes for small tools and supplies, and boxes or kegs or half-barrels for different kinds of scrap. Long handled tools, bars, etc., may be stood on end with the tops resting in inclined



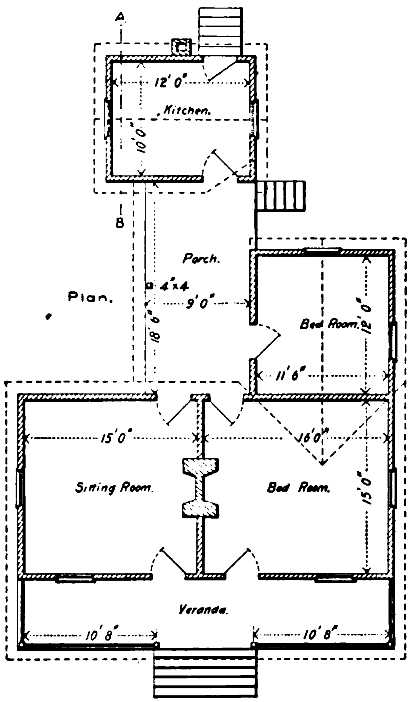


Fig. 139.—Section House; Louisville & Nashville Ry.

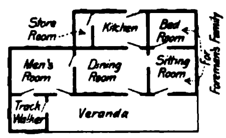


Fig. 141.—Plan for Section House.

notches in a shelf. Edge tools should be placed where they are not liable to injury. There should be a locker or cupboard for special or expensive tools and supplies, and this may be placed in a room partitioned off and fitted with a desk for the use of the foreman in writing up his reports, time books, requisitions, etc. A sliding door, carried on an overhead rail, like a freight car door, is generally preferable to double swing doors, as

being more easily handled in stormy weather, and less likely to get out of order or to be damaged by being swung to and fro.

The standard tool house of the Lehigh Valley Ry. is 16 x 20 ft. inside; and has the narrower gable end towards the track, with a wide sliding door for the hand-car at one side, and a smaller door for the men at the other side of the same end. As the sliding door fouls the smaller swing door when open, it would probably be better if the smaller door were placed in the side of the house, although, of course, a man is not likely to try to open this door

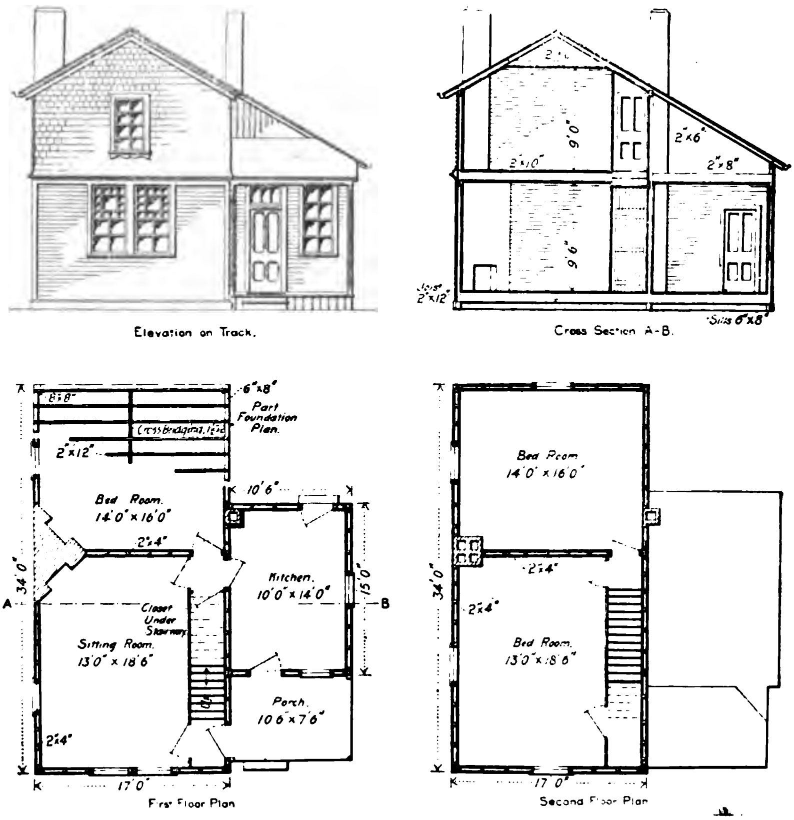


Fig. 140.—Section Foreman's House; Louisville & Nashville Ry.

when the large door is open. The building has a foreman's room, 6 x 8 ft., in one corner; and at the rear end of the house are a fireplace and work-bench. A very neat and convenient design for a large tool house is that of the Pennsylvania Lines West of Pittsburg, shown in Fig. 137. It is 15 ft. 2 ins. long and 13 ft. 3 ins. wide in the clear inside, and has the hand-car track in the middle, with room for the hand-car and push-car, as shown by the dotted lines. Double swing doors are used, but there is said to be no trouble in handling them. The general construction and arrangement are clearly shown. The building is painted in two shades of light greyish brown, and the average cost is about $175.

Section Houses.—In order to have the trackmen live on their sections it is often necessary to provide houses for them, the foreman very generally boarding the single men. Sometimes these buildings are very cheap and unnecessarily bare in appearance, but as a rule they may be made quite attractive with very little expenditure. Fig. 138 shows a very plain house of the Canadian Pacific Ry. In "Engineering News" (New York) of May 26, 1892, were shown some simple but neat and inexpensive little houses

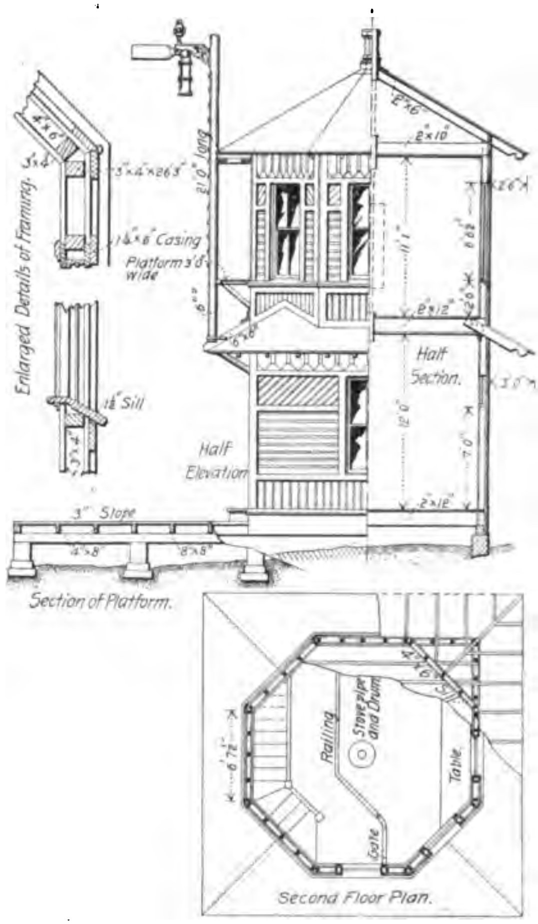


Fig. 142.—Telegraph Tower; Chesapeake & Ohio Ry.

built for the negro section hands on the Macon & Birmingham Ry. The cost of these was only about $200, and to avoid monotony three or four different standard designs were used.

Boarding houses should be well built, roomy and convenient. They should be made comfortable and kept neat, and these requirements are specially important for buildings far from a town, as good men will not stay in unpleasant quarters. Sometimes the house is furnished to the fore-

man, free of rent, the foreman undertaking to keep it in good condition and repair. On some roads a prize is awarded annually for the best kept section house and grounds. A simple and convenient plan is shown in Fig. 139, which is the standard section house of the Southern Division of the Louisville & Nashville Ry. The section foreman's house of the Louisville & Nashville Ry., Fig. 140, has sills 6 × 8 ins., upon which are floor joists 2 × 2 ins., 17 ins. c. to c., connected by a line of cross bridging 1½ × 2 ins. The studding is 2 × 4 ins., resting on the sills, with weather boarding outside and inner finish. The joists of the second floor are 2 × 10 ins., and the rafters and ceiling joists 2 × 6 ins. The house is 34 × 17 ft., with an extension 10 ft. 6 ins., × 15 ft. at the middle of the rear. All the rooms are 9 ft. 6 ins. high. On the first floor are a sitting room, 13 × 18½ ft.; a bedroom, 14 × 16 ft.; and a kitchen, 10 × 14 ft.; while the second floor has two bedrooms, 13 × 18½ ft. and 14 × 16 ft. A sketch plan of a dwelling house for section men is shown in Fig. 141.

Telegraph and Signal Tower.—A very neat design of tower for telegraph operators, signalmen, etc., is that of the Chesapeake & Ohio Ry., shown in Fig. 142. It has two rooms, the lower one square and the upper one octagonal. The platform sills, joists and floor are of oak, while the timbers of the tower are of heart pine. The construction is sufficiently clearly shown in the cut. The building is painted in buff and white, in the colonial style.

Watchman's Cabin.—The cabin for watchmen, gatemen or switchmen may be square or octagonal, the latter giving the better view, and if two of its sides are extended to meet at right angles, the extra space will afford convenient room for a long bench or a berth. The cabin should be not less than 6 ft. square or diameter, 7 ft. high inside, and fitted with a locker, chair and stove; also, perhaps, a shelter over the sidewalk where the man stands when operating the gates. For suburban crossings, where appearance of the cabins is to be considered, very neat and tasteful designs can be built at small expense. The comfort of the men should be carefully looked to, inner lining and ceiling or a layer of felt or tarred paper being used where the winters are severe. Similar cabins may be used for watchmen, yardmen, car inspectors, weighing machine men, etc. In yards where the railway runs through the streets it is sometimes necessary to place narrow cabins between the tracks or between the track and the roadway, and they may be made about 3 ft. 8 ins. × 8 ft. 3 ins. for this purpose. The cabins should, however, never be placed between tracks which are less than 15 ft. 6 ins. apart, c. to c. The sizes of timbers may be approximately as follows:

Mudsills	6 × 8 ins.	Rafters (16 ins. apart)	2 × 4 ins.
Sills, belt rail and wall plate	2 × 3 "	Door planks	¾-in.
Door and corner posts	3 × 3 "	Side planks (weatherboards)	⅞ "
		Roof planks (with tin)	1 "

Station Platforms.

Railway station platforms are, in this country, usually level with or only a few inches above the level of the rail heads, except for elevated and some suburban railways, where high platforms are used, level with the car floors (on the English system), as already shown in Fig. 94. The platform should in general not be more than 12 ins. above the rails (the standard for suburban stations on the New York Central Ry. is 12 ins. above the ties), but should be such as to be within easy and convenient reach of the lowest steps of the cars. The edge of the platform should be 24 or 33

ins. from the rail, and the main part of the platform should not be less than 10 ft. wide, but at small stations the portions beyond the station building may be reduced to 6 ft. in width. The platform should be level with the floor of the station building, and incline slightly towards the track. The ends of the platforms should have an incline of 1 in 10 to the ground level. Where there is much passing across the tracks (though this should be avoided wherever possible) planking may be laid between the rails and between the tracks, being flush with the tops of the rails, and leaving the necessary flangeway. Freight platforms should be level with the floors of the cars, being about 3 ft. 8 ins. or 4 ft. above the rail, and having the edge about 3 ft. from the rail, this clearance limit varying on different roads. A platform about 3 ft. 3 ins. high should also be provided for loading freight from or upon wagons and carts, an inclined approach being built in each case. Where a majority of the freight is moved in one direction, the platform may be given a slight inclination in that direction. In some cases the passenger platform is carried along in front of the high freight platform, each being 6 ft. wide, and the edge of the latter being about 8 ft. from the rail, but this is awkward for handling freight, as bridging planks have to be thrown across to the car. It is better to extend the freight platform to the clearance limits, and the passenger and freight platforms should be connected by an easy incline for baggage trucks. etc.

For terminal and important stations (freight and passenger) concrete or flag paving is very generally used, and the former is an excellent material, providing that it is of such quality that the surface will not readily become slippery. A cheap cinder concrete may also be used for ordinary platforms, having a curb of brick or wood. Where brick paving is used it is generally uneven and noisy, owing to poor foundation and the use of ordinary cheap building brick. Good paving brick on concrete should stand well, and special hard paving bricks, $9\frac{1}{2} \times 4\frac{1}{4} \times 4$ ins. have been used, being laid on 2 ins. of sand or 6 ins. of gravel, tamped to surface, and the joints properly grouted. Wood, however, is the usual material for platforms, and where the surface is to be level with the rails, it may have pine planks 3×6 or 2×4 ins., nailed to oak sills 4×6 ins., laid at right angles to the rails and 24 to 30 ins. apart. The timber, however, is liable to be damp and to rot, even if laid on sand, gravel or cinders, and under such conditions it will gradually develop holes which are likely to trip persons walking on the platform. It is much better to support the sills on small concrete or masonry piers, excavating the ground so as to leave an air space under the platform. For a platform 18 ft. wide, the sills may be 6×10 ins., 18 ft. long, with the ends and middle supported by brick piers 12×12 or 16×24 ins., about 3 ft. deep; or if the building has a masonry foundation the wall may be benched to carry the ends of the platform sills. The piers are 10 or 12 ft. apart, c. to c., longitudinally. The sills slope 2 ins. towards the track. Upon the sills are joists or floor beams 3×8 ins., 16 ins. c. to c., laid parallel with the track and braced by bridging pieces. To these beams are spiked 2-in. floor planks. A layer of ashes or gravel should be placed under the platform, with its surface at least 6 ins. below the sills, so as to prevent the growth of weeds. For freight platforms the stringers may be 3×12 ins. Instead of the piers, oak posts or pile ends may be used, set 8 ft. apart, and having sills 10×10 ins. drift bolted to them. For the ends of small platforms extending beyond the station buildings an economical plan is to lay two lines of timbers 7×15 ins., con-

nected at intervals of 10 ft. by transoms 6 × 12 ins. (laid flat) and ⅞-in. tie-rods, forming a box to be filled with ashes or gravel. The timbers, sills, planks, etc., may be treated with a preservative process, or painted with some preservative composition, such as carbolineum, fernoline, pinoline, woodiline, spirittine, etc.

Floors.--For roundhouses, etc., brick is probably the best paving material, as it will stand heavy trucking, and is easily drained and kept clean. Hard burned vitrified brick should be used, laid on 2 ins. of sand or 12 to 18 ins. of slag or gravel, tamped level and grouted with hot tar. At the pits, the rails may rest on timbers 12 × 14 ins., supported by brick piers 6 or 7 ft. apart, built up on the sides of the pit walls. Wooden floors are often used, having the planking spiked to sills (of old car sills or ties) embedded in cinders. Such a floor is rarely kept in good repair, but it is better than a floor of loose gravel, the dust of which is blown over the engines.

For tracks in shops, the rails may be laid on longitudinal timbers or cross ties (with wooden or iron cross ties under the former) embedded in or laid upon concrete; a tie-plate being placed under the rail ends at each joint, They may also be laid directly upon the concrete, being held by clamps and nuts on 12-in. bolts bedded in the concrete and having anchor plates on the lower heads. A groove or channel about 6 or 8 ins. wide should be left for each rail, to be filled in after with concrete, so that in renewing rails, etc., the concrete of the main floor will not be broken. A concrete floor of this kind may be made as follows: 12 ins. of gravel, tamped and leveled; 3½ to 4½ ins. of concrete (2 to 4 sand, 4 fine gravel and 1 cement); 2 ins. of cement (5 sand to 1 cement), and a ½-in. finishing coat of equal parts of sand and Portland cement, or 1½ ins. of sand and cement 2 to 1. A tar concrete floor may be made of a layer of clean, fine gravel and sand, well mixed with pitch and tar (1 part pitch to 2 tar), the layer being 1 to 2 ins. thick and laid on a 6-in. bed of gravel or of broken stone mixed with gravel to fill the voids.

Plank floors laid directly upon cement concrete are subject to rapid decay, as the cement is hygroscopic and contains water in the pores, and is a good conductor of heat. Concrete of asphaltum, on the other hand, is a poor conductor of heat; it is antiseptic in its properties, and the floors placed upon it have proved very durable, though the pungent smell of the tar lasts a long while, and may be objectionable where certain goods are stored. The use of tar concrete is not advisable where heating pipes come near it, and in cement concrete fine crushed granite, in place of sand, will give a more durable and better looking surface. For the wood floor on top of the tar concrete, 3-in. square-edge hemlock is recommended, covered with 1 or 1¼-in. maple, laid at right angles to the hemlock and well nailed. The bottom planking should be well seasoned, and painted with some preservative, otherwise dry-rot may set in where any considerable area is covered by machines.

CHAPTER 12.—SIDETRACKS AND YARDS.

Sidetracks may be considered as divided into two classes: 1, Those used for passing trains on single track, or to relieve traffic on double track roads (as in allowing freight trains to get out of the way of faster passenger trains and at the same time to continue their own course on the relief track); 2, Those used for cars standing at yards and stations. The track of sidings is generally inferior to that of the main tracks, having lighter rails, fewer and older ties, and a lesser equipment of spikes and bolts. This may be permissible to a certain extent, but the sidings should nevertheless be kept in good and safe condition for service. The ordinary yard and freight sidetracks (except at important points) are very often the last resting place of old material. before reaching the scrap heap; and the ties are allowed to rot in peace, and the spikes and bolts to remain comfortably loose. As a general thing it may be considered that a sidetrack in this condition, with a wavy surface and irregular line, is an indication of careless practice or neglect in the maintenance department. All turnouts should be well laid and ballasted and kept up to the standard of the main track, while the maintenance of sidings of the first class noted above should be as carefully attended to as that of the main track.

Freight sidetracks at small stations may be placed to suit local requirements as follows: (1), at the back of the station building; (2), between the main track and the station, or on the outer side of the main track; (3), between two separate buildings for passenger and freight service. Where practicable it is a good plan to have such sidetracks slightly lower than the main track, so that cars on the former will not run down or be blown along, so as to foul the main track. On the approach of winter the ditches should be cleaned out and the ballast dressed, to facilitate drainage. Sidetracks for standing cars should have a derailing switch or else a stub track parallel with the main track, having the switch set normally for the stub, thus avoiding derailments. Another appliance for the same purpose is an automatic cut-out in the form of a short pivoted piece of rail, moved horizontally by wire or 1¼-in. gas pipe connection with the switchstand. A scotch block may also be moved in the same way. The best plan is to have the stub track instead of a derail, this track being a continuation of the side track, and its rails may be lower than the track rails and covered with 3 to 5 ins. of sand to absorb the motion of a runaway car. The switch of this stub is set normally for the stub track, to prevent both fouling and derailment.

Arrangements for "lap" passing sidings are shown in Fig. 143, the first four being used on the Pittsburg, Fort Wayne & Chicago Ry., to suit local conditions. Plan No. 1 is a middle siding with the pulling-out switches at the tower. Westbound trains take the siding at A and pull out at B; while eastbound trains take the siding at D and pull out at E. Each of the two sidings will hold four trains, which requires 4,300 ft. of track on the Eastern Division. The sidings are connected and have the end switches C and F, so that in case of emergency the entire length of track can be used for trains in one direction. The telegraph tower is located at the center, or "lap," the switches B and E being operated from the tower.

This relieves the trainmen from responsibility for the switch when they have a clear signal to go on and prevents them from pulling out onto the main track without the knowledge of the operator. Plan No. 2 is a middle siding in which trains pull in at the tower. Westbound trains enter at B and pull out at C; while eastbound trains enter at E and pull out at F. This plan is not used as much as the former. As the entering switches B and E are operated from the tower, trains do not have to stop before taking the siding. In order to control the outgoing movements and place the sidings entirely under the control of the operator, an electric starting signal may be placed at the pulling out switches C and F. This is operated from the tower and interlocked with the switch, so that a train cannot pull out without the knowledge of the operator.

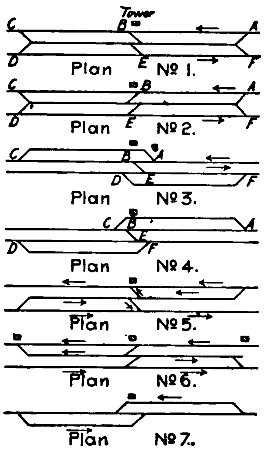


Fig. 143.—Plans of Lap Sidings.

Plans Nos. 3 and 4 are outside lap sidings, the operation of which is similar to that of Nos. 2 and 1, respectively. These outside sidings are used on long, straight lines to avoid the necessity of putting the reversions in main track, which the construction of a middle siding would require. The capacity of the siding for trains in one direction cannot, however, be temporarily increased, as with middle sidings, except by crossing over and interfering with through traffic in the other direction. On the Eastern Division, the lap sidings are placed at intervals of ten miles, the intention being to build additional sidings between them as the traffic may demand. By having sidings with a capacity for four trains, at intervals of five miles, with switches operated from a tower so that trains need not stop, a maximum facility of train movement is obtained. When the traffic becomes too heavy for such a movement an additional main track or tracks will be required. On the Pennsylvania Ry., the arrangement shown in Plan No. 5 is used where the sidings hold only one or two freight trains and also where it is desired to maintain only one telegraph office. Where the third tracks are of such length as to lap over two block sections and get the use of these telegraph towers, the connections are made as shown in Plan No. 6. A similar arrangement to Plans No. 3 or No. 4 can be applied to single track, as shown in Plan No. 7, and this greatly facilitates the handling of heavy traffic. With such an arrangement, two trains, headed in opposite directions and waiting upon the sidings, may proceed upon their respective ways immediately after the passage of the train on the main track, without waiting upon each other's movements. These sidings may be long enough to accommodate two or more freight trains, each of which pulls out as it gets the signal from the tower, the other following up to the tower. Thus trains in opposite directions do not interfere with one another, and no time is lost in waiting for train orders from a tower at a distance. The switches may be operated from the tower, the signalman being noti-


Fig. 144.—Lead Track in Yard.

fied of the train orders. These sidings may be eventually extended to form a double track.

On many roads having double track, relief sidings are extensively used, placed between or outside the main tracks, as already shown, and these are sometimes long enough to be used as a running track. If they are short, they may have a switch at one end only, thus avoiding facing switches, and obliging trains to back into the sidings. Where a middle relief track connects with the crossover connecting the two main tracks, the movement of trains from the relief track may be governed by the dwarf signal at the crossover switch. In order to allow of a second train being got clear of the main track when the relief track is occupied, the train may be switched onto the opposite main track, a call bell connected with the block signal tower and interlocked with the dwarf signal being used to control the heading out of this train. Similarly, where a train takes an outlying sidetrack on a block section, and the block is thus clear and yet has a train on it, the towerman is notified and gives a following main track train the green signal. In such cases a bell circuit connects the outlying sidetrack with the tower, by which the trainmen can notify the signalman when the train is clear of the main track.

Yards and Terminals.

The freight yards are a very defective part of the railway system as a whole, and one reason of this is that the great expense involved in switching and handling cars in railway yards has only been fully recognized by operating officers within very recent years. While there are many yards which are well laid out for economical operation, yet as a rule the general design and detailed arrangements of yards have been made more or less at hap-hazard, with consequent difficulty, delay and expense in handling the traffic. Probably a majority of the yards of any importance have developed gradually from smaller yards laid out originally without much care, and the tracks have been lengthened and new switches and tracks put in here and there from time to time as immediate requirements seemed to demand.

Defects in yard design are very frequently due to a lack of co-operation between the constructing and operating officers. In some cases a yard is enlarged or extended without the assistance of the engineer, and the result is an awkward arrangement of curves and switches which increases the difficulty of handling cars and increases the wear on rails and wheels. In other cases the engineer has sometimes planned and located a freight yard without inquiring into the local conditions and the traffic requirements, with the result that the yard, while appearing very convenient on paper, is a source of much trouble to the operating department. Thus the switches may be badly located, or the track scales, repair tracks, or other special points may be so located that they can only be reached by crossing or fouling other tracks which are in constant use.

Most railway engineers give too little study to the operating side of railway service, and in consequence do not realize the importance of many smaller items and details in economizing work, or realize their relation to the general operating expenses of the railway. For these and other reasons it is imperative, in the interests of efficient service, that the officers of the constructing and operating departments should consult together as to the best arrangement for any one yard, while information should be

sought from the yardmaster or other local officer as to any special or local service to be provided for, or any special difficulties resulting from the existing arrangement. As already noted, this practice very rarely obtains, and yards are as a rule extended or enlarged piecemeal and without any consideration as to the relation of the new tracks to the general plan of the yard. Such a yard becomes eventually a mere patchwork of additions and extensions added on to a small original yard, the involved and complicated arrangement then resulting in much extra maintenance work and in much unnecessary work and delay in handling the traffic. In large yards the traffic is usually so heavy that entire reconstruction is practically impossible, but a good design should be planned, and no important changes should then be made on the ground until the plans for such changes have been compared with the general plan, and the reasons for the changes carefully considered by the officials familiar with the regular handling of the traffic.

The main idea in enlarging a yard is usually to provide more tracks for cars to stand on, for the too general idea of a yard is that the principal consideration is to have plenty of tracks upon which to store cars, while as a matter of fact a yard is intended for sorting and distributing cars and not for storing them. The quicker the car is passed through the yard from the time of its arrival off the road until it is delivered at its unloading track or sent out again to continue its journey, the greater will be the operating efficiency and economy of the yard service. This economy and efficiency will also extend through the whole freight service, for if the cars are handled promptly there will be less delay in providing empty cars as called for, and consequently the capacity of the equipment will be increased, thus avoiding the necessity of purchasing new cars. If a yard is too large, or its track capacity too great, there is likely to be a lack of promptness in clearing it and getting the cars moving over the road. On the other hand, if it is too small, blockades will almost certainly occur, interfering with the movement of freight trains on the road, while the hurried and complicated switching in an overcrowded yard will tend to greatly increase the damage to rolling stock. In all yards there is more or less of a tendency to rough handling of cars, which can be kept in check only by strict enforcement of discipline and a full enquiry as to the cause of and responsibility for each case of damage.

One important defect resulting from the general failure to recognize the relation of yard service to the general operation of a railway system is the common failure to provide proper equipment. Any old rails and track material are considered good enough for yard tracks, and the average condition of the ordinary locomotives for yard switching is only one remove above that of the locomotive allotted to the despised gravel train, although it must be admitted that there is a growing recognition of the expense involved in using worn-out road engines of light power for work-train service. Not only are the yard tracks very often of bad construction in the first place, but their maintenance is more or less neglected, and low joints, missing bolts, loose spikes, worn ties, and switches and frogs in various grades of bad repair are common conditions to be met with in the average yard. This is partly due to weakness of the tracks as originally built, for the sectionmen in charge of the yard, finding it impossible to keep all these tracks in proper condition under the traffic which they sustain, naturally become more or less careless and discouraged.

The condition of the switching engines is frequently on a par with that

of the track, the tires being worn hollow to an extent which is most destructive to the track, while the valves are badly set, and all the connections are more or less loose. It is not in the nature of the average engineman to give his best endeavors to the proper handling of such a "mill," so that the amount of damage to cars in switching will probably bear some relation to the amount of maintenance expenses for tracks and engines. Another point which may be mentioned in this connection is the failure to provide proper lighting for the yards, night work being done under adverse conditions by the aid mainly of small hand lamps. It must be admitted that the proper lighting of a yard is not an easy matter, owing to the interference of cars, whose black shadows alternating with lighted spaces, and moving from place to place, may be more dangerous than a uniform darkness to which a man's eyes become more or less accustomed. Nevertheless the matter is not impossible of solution, and there are already some few yards which are efficiently lighted.

The use of heavy rails, or even of good rails, in yards, is very generally assumed to be unnecessary and uneconomical in view of the severity of the service and wear, and this is one reason for the dilapidated yard tracks which are so common everywhere, except at a few recent passenger terminal yards. The New York Central Ry. is now introducing its 100-lb. rails in the passenger yards of the Grand Central terminal station, New York city, and the results thus far obtained show a decided economy in track work, in conjunction with other advantages. The yard has about 12 miles of track in all, laid originally with 65-lb. rails. The tracks now laid with the 100-lb. rails include those carrying the heaviest traffic between the station tracks and the four-track main line approach, and they are equipped with split switches, slip-switches, turnout frogs and crossing frogs, all of the 100-lb. rails. The yard is controlled entirely by interlocking plant, and the lever men in the main tower at first objected to the heavy switch rails, claiming that it would be very hard work to throw them. As a matter of fact these switches are found to work even more easily than those with 65-lb. switch rails, as the latter become bent vertically, causing them to bind and slide hard on the slide plates, whereas the former are stiff enough to hold their shape. In 1896 the yard force for track work averaged 20 men, and the only Sunday work was for renewals and large repairs. Formerly the regular gang averaged 32 men, with about 16 extra men, and maintenance had to be carried on regularly on Sundays. Then constant work was required, and the tracks had to be surfaced about once a month, while the new tracks are left for months without any attention. The switch engines running on the broad heads of the heavy rails will show less wear of the tires than when running on the narrower-headed 65-lb. rails, and this again will result in less wear and flow of the metal in the rails, and less injury to frogs and switches. With the more substantial track there is a noticeable decrease in derailments, which are usually more or less frequent in yards, while the tracks ride much more smoothly than the older tracks. The facts that good heavy new rails will reduce the wear of both tires and rails in yards as well as on the open road, and that the expenses of maintenance of track and equipment will be correspondingly reduced, have probably never occurred to many officials, and they have felt that it would be waste of money and material to put such rails in their yards.

Split switches should be used, of a uniform pattern, and frogs should be

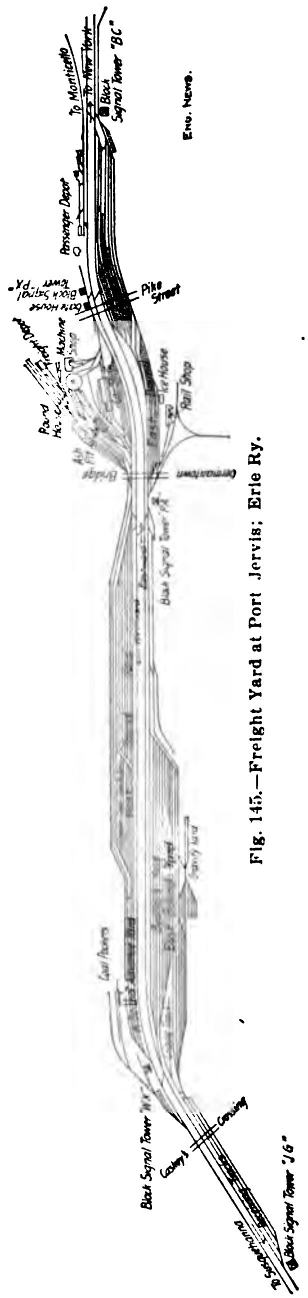


Fig. 145.—Freight Yard at Port Jervis; Erie Ry.

as far as possible of one number. No. 7 frogs are largely used, corresponding to curves of 12½°, and frogs of a lower number should not be used except in special cases, although on the other hand, it must be remembered that the easier curves of frogs of higher numbers require longer leads, and consequently more yard space. The Chicago, Burlington & Kansas City Ry. uses a No. 7 frog in 1 to 6 ladder tracks, putting in a short curve beyond the point of frog. Complicated arrangements of switches, slip-switches, double crossovers, etc., should be avoided. Slip-switches, though valuable and often necessary, are expensive in first cost and in maintenance. The tracks of each group should be parallel and not closer than 12 ft. c. to c.; while the car repair tracks should be 20 ft. c. to c. Tracks for cars to be unloaded by teams should be 24 or 26 ft. c. to c., to allow for the passage of wagons and teams between the cars (or else space should be provided for teams to turn at the end of the track), and the space between these tracks should be macadamized or paved with brick or stone if there is much trucking, or at least well coated with cinders, so as to prevent mud and enable the wagons to be hauled easily.

The tracks should be developed from one or two principal sidetracks or ladder tracks, so as to avoid putting switches in the main track beyond the one switch leading to the receiving track. These receiving tracks should be of sufficient capacity to avoid blocking the main track by a second freight train while the first is being inspected, marked and distributed. A series of parallel sidetracks may be developed from a diagonal lead track connecting with the main track or principal sidetrack, as in Figs. 144 and 218. The yard will be in two parts, one for incoming and one for outgoing trains, and each part of the yard will have groups of tracks for sorting and storing cars and making up trains. The yard should be located on a straight part of the line, and the main track may pass through or around it, provision being made for a route around or through the yard, respectively, in case

of any block on the main track. In staking out tracks in a large yard, stakes of different colors for different tracks, may conveniently be used to avoid confusion, and stakes marked "M. S." and "P. F." may be used to mark the mouth of switch and point of frog.

The switchstands should be of good make and kept in good order, and if the numbers of the tracks are painted on the switchstands or targets the work of the yardmen will be much facilitated. Usually the yard switches are worked independently, but in a large yard with heavy traffic it is better to have them interlocked and worked from towers, in order to simplify the switches and switch movements, while in some large yards, such as those at Altoona (Pennsylvania Ry.) and Galesburg (Chicago, Milwaukee & St. Paul Ry.), the switches are worked by compressed air, with the Westinghouse non-interlocking apparatus. An ample supply of ties, slide plates, etc., should be provided for yard switches, and the whole yard should be well ballasted, well drained and kept in good condition, one or more men being also engaged to clear up scrap iron, paper, refuse, etc. A difficulty experienced in most yards is that of keeping the surface of the yard neat and free from weeds. The yard gangs have other and more important work to attend to and have little time to give to this incidental work, with the result that the surface gets irregular, and weeds grow thickly on little used tracks, making the general appearance of the yard unsightly. A machine that could be used for such work would be a welcome addition to the equipment of a yard section gang.

A few words may be said as to the laying out of tracks in freight houses on a water front. Where piers and warehouses are built with a dock on each side, from one to three tracks are required down the middle of the pier, with trucking space on the outside, between tracks and edge of pier. Where warehouses are parallel with the wharf front, space can be economized by having tracks enter the building at the side, and run at right angles therewith or nearly so, and about half way across the width of the building. This method will give more car room, or rather more loading room, than where the track is parallel with the building. This is especially the case where tracks are in pairs, say 12 ft. c. to c., with trucking space of 15 to 20 ft. between pairs, putting in as many sets of tracks as are needed. The ends of tracks should be within reasonable distance of wharf front to save as much as possible in the work of trucking, a very considerable item of expense in handling freight. In Europe, hydraulic power is largely used for operating cranes, capstans, car elevators, turntables, etc., for handling freight at terminals.

The freight yard at Port Jervis, on the Erie Ry., is shown in Fig. 145. The main tracks pass through the middle of the yard, and the yard tracks aggregate 42 miles. The receiving yard for eastbound trains has, in addition to five receiving tracks, a double gravity track with a grade of 1.25% and about 800 ft. long, or of sufficient capacity to hold an eastbound train, and at the bottom of this track are seven classification tracks by which cars are sorted for the next division. By this arrangement one man can sort 100 cars per day in station order.

The yard extends from JG to BC block station, a distance of 2.9 miles, and will hold 4,200 cars. All connections with the main tracks are at block stations, so that these tracks can be fouled only at such points as are protected by block signals. Eastbound freight trains generally enter the yard at JG station, and are left there for classification. The three

tracks nearest the main tracks in the eastbound yard are also "receiving" tracks, being used for that purpose when those at JG are filled. In this case the trains enter the yard at WX block station. The caboose is cut off at JG or WX, as the case may be, and allowed to run down the main track by gravity to a caboose siding. The cars are classified in the "eastbound" yard, and thence taken in solid trains by yard engines to the "eastbound advance" yard, whence they are taken by road power to leave the yard at BC block station. The local cars are switched out and set on the four available tracks west of the "gravity yard," after which they are placed on the two "gravity" tracks, which hold a maximum train. Westbound freight trains enter the yard at block station PA. The cabooses are cut off about 1,000 ft. east of station BC, and drop by gravity into the "eastbound advance" yard, whence they are taken as required by eastbound trains. The general operation of the "westbound" yard is about the same as that of the "eastbound," except that there are no gravity tracks. The track next to the main track, and the one on the extreme outside of this yard are kept open to facilitate the movement of engines to and from the coal pockets. Westbound trains leave the yard at station WX. The arrangement of the yard is fairly satisfactory, but like most yards in this country it has been developed from time to time without any special arrangement in view.

At the block tower at the entrance to the yard is a fixed red light, and the signalman is forbidden to show the hand green light until a train has slowed down for the red. This effectually prevents fast running through the yard. At the second tower in the yard (the yard being divided into four block sections) there is also a fixed red signal, with a green lamp below, lighted by electricity. This light is switched in by the signalman when notified that the block is clear, but the key is so arranged that he cannot fix it to display the green continually, as may sometimes be done by careless signalmen when a green hand lamp is used. It will be seen that trains are never given a clear signal through the yard, but only the green or caution signal.

Where the block system is not used, freight trains should be required to stop at the yard limit sign, unless the track is plainly seen to be clear, and then proceed carefully into the yard, rear flagging being required within this limit, except when the freight train (or engine) is running on the time of a first-class train.

Where large yards exist in busy city districts it would often be real economy to sell the land and lay out new yards in an outlying district. If, however, the conditions are such that the yard must be kept, then it will be economy to see how far space can be economized, so as to get as great a concentration of work as possible. In this respect English railway practice is largely superior to American practice. The great attention paid to this matter, in England, necessitated by the very high value of land, has enabled them to devise methods for handling enormous quantities of freight in city terminals of restricted area, while even the outlying and divisional terminals are laid out with greater care and with a greater attention to the operating side of the question than is common in this country.

The discussion in detail of the existing arrangements of individual yards can be of but little value, since the conditions and requirements, and the nature and extent of the traffic, are so diverse; and what may be a proper and desirable plan at one yard may be entirely inapplicable at another. Fur-

ther on, however, are given some extracts from a paper by Mr. W. L. Derr, Division Superintendent of the Erie Ry., on "Railway Yards and Terminals," which was published in "Engineering News," New York, June 18, 1896. It is a comprehensive article on the principles involved in yard design and yard work, and the points to be specially considered in a typical design. The details of the design of any actual yard should conform as closely as possible to these general principles and general rules. It may be said without hesitation that on nearly every railway it would pay to have an extended and systematic investigation made as to the construction and operation of each important yard, and as to the means by which increased efficiency and economy can be secured; and then to follow such an investigation by a prompt and systematic undertaking of the improvements which are found to be desirable and practicable.

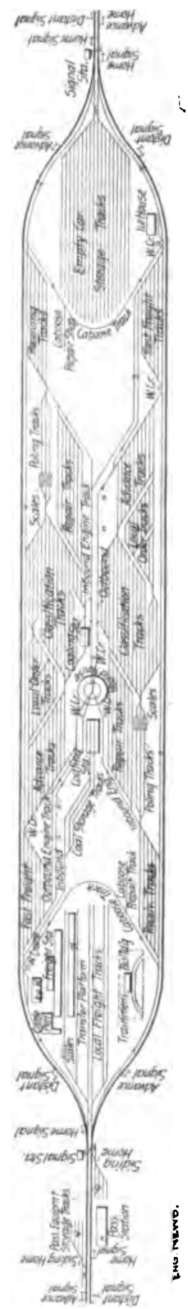


Fig. 146.—Typical Plan for Freight Yard.

"The following general proposition may be stated as a fundamental principle in yard working: Cars that are to be held at a yard must be kept apart from those in the regular movement, and separate tracks must be provided for the 'hold' cars. To a violation of this principle, more plainly than to anything else, may be traced the delay to cars in yards, for, as will readily be seen, 'hold' cars, when mixed in the regular movement, require a continual handling, having to be switched out every time the tracks they are on are worked. Yards otherwise poorly designed may often be operated in a fairly economical manner by providing storage tracks for the 'hold' cars, both empty and loaded. It follows that, to secure order, separate tracks must be provided for cars of the different destinations.

"All general movements of the traffic should be forward ones, and only under great stress are backward movements to be made. This point cannot be too firmly impressed upon those designing yards, as to neglect it will ever after cause great delay to the yard movements. Promptness in moving locomotives between the yard and the engine house is necessary, and the tracks should be so arranged that an incoming locomotive can, after placing its train on the receiving track, proceed immediately to the engine house. Where engines have to be changed quickly, as at division terminals in the case of the engines of passenger trains, a track should be placed near the changing point, for the accommodation of the incoming and out-

going engines. The coaling station, ash pits, sand house and water supply should be near the round house, and be accessible at all times.

"A freight yard, of which a typical arrangement is shown in Fig. 146, should have receiving tracks of the length, each, of the longest incoming train, for the reception of the trains as they arrive at the yard; 'poling' tracks, if the poling method of switching cars is practiced (where there is not sufficient length of yard for poling tracks the 'poling' can be done direct from the receiving tracks); classification tracks—one for each classification; advance tracks to receive cars taken from classification tracks, and upon which trains are to be made ready to be sent forward; short tracks, commonly called a 'gridiron,' holding from five to ten cars each, and used in classifying cars in station order for the division in advance; tracks for storing empty cars; tracks for 'cripple' or damaged cars, and tracks for cars with fast freight. 'Poling' and classification tracks may be of any convenient lengths. For poling tracks this would be about the length of an incoming train. For the shortest classification track, in order that switching may be continued during a temporary blockade of the main line in advance, it would be a sufficient length to hold the cars of that classification of several hours' working. Where there are advance tracks the classification tracks may be somewhat shortened, but it must be borne in mind that the filling of one classification track blocks the classification of cars on all the others until the filled track is relieved. Spare tracks should, therefore, be provided near the classification tracks. Very long yard tracks are not desirable, for several reasons; among which are the high speed required to pass cars to the extreme ends of such tracks (especially if the switching is done against a rising grade), and the great delay and consequent expense in returning the men to the switch engine after they have taken cars long distances. Separate tracks for stored empty cars should be provided in order to keep these cars out of the regular yard movement, which they would otherwise greatly complicate.

"If cars with fast freight and those with slow freight are handled on the same classification tracks, they will become mixed, causing serious delay to the fast freight. The latter should be handled on separate tracks next to the main track in the classification or in the advance portion of the yard, or, better, a set of tracks in advance of all the other tracks, so that the fast freight will always be ahead of the slower. The care of disabled or 'crippled' cars must be provided for, and the faster the traffic the greater the necessity for facilities for the prompt handling of these cars.

"The tracks for cabooses or cabin cars should be so located that the cabooses can be got out of the way quickly on their arrival at the yard and yet will be accessible, without undue handling, to outgoing trains; and, if practicable, as soon as these cars arrive at the yard arrangements should be made to so place them. When there is room for it, a loop caboose track reaching from the receiving tracks, incoming, to the advance tracks, outgoing, will be found to be a convenient arrangement. When certain trains are run regularly by one set of crews and others by another it will facilitate matters to keep the two sets of cabooses separate, by providing a double caboose track.

"Heavy track scales should be placed at the entrance to the classification tracks, so that cars can be weighed while being switched. They should have a separate 'dead' track, permitting cars that are not to be

weighed to be passed over without affecting the scales. The location of scales for local purposes will, of course, be governed by local requirements.

"The location of the yard with reference to the main tracks is an important matter. The yard may be placed on the outside of each main track, or to one side of both the tracks, or between them. The first plan is objectionable on account of the necessity of crossing the main tracks in passing from one side of the yard to the other; and the second on account of the traffic in one direction crossing the other main track to get into the yard. The third plan, that of placing the yard between the main tracks, is open to neither of these objections, and, if it further provides for the sufficient separation of the main tracks to make room for the engine house as well, the yard movements will not foul the main tracks from the time the trains leave the main tracks when entering the yard until they come on them again when leaving the yard. Main tracks so located should, when practicable, be placed far enough from the yard tracks to admit of additional tracks being built in the space, as required. At points where there are yard connections with main track the connections may be so arranged that ordinary switching movements will not cause the main track to be fouled when the switch is set for the main track movements. This may be effected by connecting the main track and the first yard track with a crossover and extending the yard track a short distance beyond the crossover, thus forming a 'run-by.'

"The track from which a series of parallel tracks start is called a 'lead,' or 'ladder' track, and is generally at an angle to the parallel tracks equal to the angle of the frogs, Figs. 144 and 218. When it is necessary to divide a series of parallel tracks without breaking their continuity, a straight lead track with slip switches is run diagonally across them, the crossing of the tracks being effected by means of crossing frogs, and connections effected by slip switches, as in Fig. 53.

√ "Where there is a large number of tracks, such as classification tracks, it may be advisable to make the entering end of the set wedge shaped in order to concentrate the switches and also to lessen the wear of the frogs and switches by trains crossing them. For the prompt operation of lead switches the levers for throwing them should be grouped, so that they can be worked by one attendant from a central station. This is not only the quickest but the safest method of operating the switches, because it avoids such misunderstanding as is apt to ensue if more persons than one handle a set of switches. The levers need not necessarily be interlocked. The switch lights are placed on stands near the points of the switches they govern and are turned by the movement of the switch rails. The lamps are provided with lenses of two colors indicating, respectively, that the switch is set for the lead and for the side track. Switch lamps should be placed close to the ground, so that they will not conflict with any block or interlocking signal in their neighborhood.

"Electric lighting is the best for yard illumination, provided the lights are located with care. Electric lights cast a deep shadow, and unless they are located high over the tracks the shadows of cars and buildings near by will be troublesome. They should never be placed near an important signal, as their strong light obscures the weaker light of the signal. Electric lights make the best switch lights, also, giving a much stronger light than oil and requiring less attention in their care and maintenance.

"The principles of signaling are the same in yards as on the line. At the entrance to the yard the main track switches should be operated from a central station and be interlocked with the signals that govern the main track movements and movements that may foul the main track.

"Water cranes should be located at the engine house, at points where switch engines work, at coal pockets (if distant from the engine house), and at the outgoing ends of the yard. A main with hydrants about every 200 ft. should be placed along the receiving tracks for the use of car inspectors in cooling journals, and in other work. There should be fire hydrants near important buildings and at points where cars are stored.

"On rapid transit lines the interval between trains, that is the 'headway,' is largely dependent on the arrangement of the terminal tracks, for in practice trains cannot be run on a headway less than the time used by a train entering and leaving a terminal. Any arrangement of track that makes it necessary to stop a train for the purpose of putting it in proper order as to engine or cars, or of putting it on the proper track for the outgoing trip, or that permits an incoming engine to be blocked in and thus necessitates an exchanging of engines, is defective, so far as the running of trains at short intervals is concerned. Quick movements can best be made by arranging for the forward movement of the trains in all cases, and avoiding the necessity of having the traffic in one direction cross the traffic in the other direction.

"The 'loop' plan of track is the only one that fulfils the desired conditions. The loop, which is simply a circular track connecting the incoming

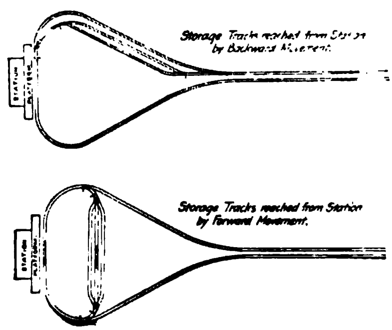


Fig. 147.—Loop Terminals for Rapid Transit Railways.

and outgoing tracks, forms a continuous track to permit trains to pass from an incoming to an outgoing track by direct forward movement. No change in the arrangement of the train is necessary, and the locomotive is always run in the forward motion. By any other plan it is necessary either to run the engine backward (thus placing the engineman on the off side, away from stations and signals), during one-half its entire mileage, or else to turn the engine at the end of each run. In addition to the main line loop a sufficient number of tracks should be provided along it, or at least, not far from it, for the purpose of storing the engines and cars which it is necessary to keep at the terminal. These additional tracks should be connected at both ends with the main track. Their exit ends should be far enough back of the starting station to make it unnecessary for a train,

after pulling out, to back up in order to reach the station. The loop plan with forward movements in Fig. 147 is, perhaps, the ideal loop track for this purpose, no backward movement being necessary in handling the ordinary traffic, either in passing from the main track to the side track or in returning to the maih track from the side track.

"At points where there is not room for a loop, space should be reserved for terminal tracks of the usual order. If the room is so limited that even these cannot be accommodated, a trailing crossover should connect the two main tracks about an engine length from the end of the incoming track, so that an arriving engine can get out of the way without having to move against incoming trains or without having to wait for the train that it brought to be taken away. There should be another crossover a train length farther back to admit of the passage of trains from the incoming to the outgoing track.

"Items which make up the cost of yard operation are, besides interest on capital invested and depreciation, the cost of yard engine repairs and supplies, wages of yard enginemen, yard firemen, switchmen, yardmasters, signalmen, telegraph operators, way bill clerks and of trackmen; a percentage of general office expenses and of wages of train dispatchers, the cost of material used in track repairs, and the cost of labor and material used in the repairs of cars damaged in the yard."

Sand Track for Runaway Cars.

In Europe use is sometimes made of a "sand-track" for stopping runaway cars, and Fig. 147A shows the arrangement in the Friedrichstadt gravity switching yard at Dresden, Germany. The cars on the two tracks of 1.8% down grade leading from the gridirons of the classification tracks to the train tracks, are controlled by portable stop blocks (similar to Fig. 135) which are placed upon the rails as required by men stationed for that purpose. It was desired, however, to install some system of stopping cars or trains which might get beyond control on the grade, so as to pre-

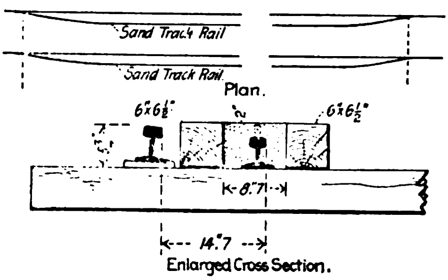


Fig. 147A.—Sand Track for Stopping Runaway Cars.

vent damage to the cars, the freight or to the yardmen, and to prevent the possibility of collision with trains, etc., in the yard at the foot of the grade. For this purpose the sand track was adopted, gantleted with the running track as shown. The running tracks have main-line rails laid on thick iron tie-plates on wooden ties. The sand track has branch-line rails laid directly upon the ties, giving a difference of about 1.05 in. between the levels of the rail heads. A guard timber is placed along each side of each rail

of the gantleted sand track, and the space between the timbers is filled with sand, giving a depth of about 2 ins. of sand over the rail. If a car gets away from the gridiron tracks, one of the yardmen throws the switch of the sand track, and the car is quickly and easily stopped, while there is no difficulty in getting it back again. There is also a sand track on the main freight track to this yard, and on one occasion a freight train of 27 cars (with 55 axles) weighing 417 tons with engine and tender, got beyond control on this grade of 1.8%, in spite of having brakemen on eight of the cars. It was diverted onto the sand track, while running at about 30 miles per hour, and ran for 328 ft. over a thin layer of sand and 738 ft. over a 2-in. layer of sand. After the train was stopped, the sand was cleared away, and the train then ran to the main track through the lower switch of the sand track, the total length of this track being 1,300 ft. The device is also used at derailing switches, a train passing a home signal at danger being diverted onto the sand track.

CHAPTER 13.—TRACK TOOLS AND SUPPLIES.

The tools used in track work are an important item in the proper maintenance of way, and it is bad practice and false economy to purchase the cheapest tools obtainable and then to pay no attention to see that they are properly and carefully used. First-class tools should always be supplied, as they need cost but little more than inferior tools, while they do better work and last for a longer time. The use of steel instead of iron enables a reduction of weight to be made in many cases, without reducing the strength or efficiency of the tools, thus increasing the facility with which the tools can be handled. Tools with parts subject to wear should be bought under a guarantee that the wearing parts are interchangeable.

Each section gang should have a complete equipment of the necessary tools and supplies, and at division headquarters, or other convenient points, should be kept those special tools of which only a few are required, such as rail saws, rail benders, etc., which usually average one to every 50 miles of track. A few spare frogs and switch rails may also be kept at these points as emergency stock. On the Chicago, Burlington & Quincy Ry. the rail-benders, cross-cut saws, wheelbarrows and scoops are kept at yards and sent out to section gangs for temporary use when needed. Two extra jacks on the division will usually be sufficient, but it is to be noted that the New York, New Haven & Hartford Ry. has a special gang to do all work requiring the use of jacks. There will be a velocipede or inspection car for the use of the roadmaster, one for each division roadmaster and one for the engineer. Also, perhaps, a ditching car with blades and mold boards for clearing ditches and trimming ballast to the required form. There may also be the following for each division or a certain number of divisions: 1, A steam derrick car of 8 to 10 tons capacity (and hoisting velocity 1 ft. per second) f(

handling stone, lumber, etc., in emergency work or repairs; 2, a flanging car; 3, a snow plow; 4, a wrecking train. At division headquarters there should be a repair shop for repairing tools, frogs, and switches; for making guard rails, and for sawing and drilling rails for such work as can be done away from the place where it is to be used.

There should be a good supply of tools maintained constantly in the storekeeper's charge, so as to be ready to equip an increase of force in case of emergency, such as a flood, washout, snowstorm, landslide, wreck, etc. But, on the other hand, an accumulation of odds and ends of old-fashioned articles and tools in the storeroom or the section tool house should be vigorously fought against. The cars of wrecking trains should always be kept fully equipped. Roadmasters and foremen should see that no unserviceable tools are kept on hand, but that when damaged or broken they are sent at once for repair, or requisitions made for new ones. The section foreman is held responsible for all the tools issued for the use of his gang, and it is a good plan to have the tools of each gang plainly stamped with the number of the section. A close check should be kept on all tools issued, and not more issued than are properly required by the section, while, except for an increase of force, new tools should never be issued until those worn out or broken are returned, their disposal properly accounted for, or a satisfactory reason given for requiring the additional tools. There should also be some organized system for sending tools between the section and the shop or store. The ordinary tag on a bundle of tools is likely to be torn off or to have the address obliterated by wet, etc., and if this occurs on a bundle sent to the shop, the tools are either held or are sent out to some other gang, while the foreman of the section to which they belong suffers from the delay. A good plan, suggested in Parson's "Track," is to have brass disks or checks, like baggage checks, with the number of the section and name of station for that section stamped on one side, and the address of the shop on the other side. Two slots are cut at opposite edges for a leather strap, so that the strap can be slipped through so as to cover one side of the check, leaving the other side exposed to show the address to which the tools are to be sent. The checks for different divisions can be made of different shapes. The carrying out of these check systems and the enforcement of the rules above mentioned, will check carelessness, and result in a greater efficiency and economy as compared with the haphazard systems in force on some roads.

Each section should have a full equipment of good tools to supply every man, and some extra of such tools as have occasionally to be sent to the shop for dressing or repair. The number of these extra tools will depend upon the method of handling repair work and the frequency of the repairs required. The number of such extra tools should be specified by the roadmaster, and the extra tools should not be put in use until the regular ones have to be repaired or renewed. For sections having stone ballast it is recommended that there should be two tamping picks at the repair shops (or on their way there) for every pick in service. A sufficient supply of shovels and scoops too badly worn to be used economically in ordinary work, may be retained to equip a double force for emergency work, as shoveling snow in winter, and a half supply of worn out picks and bars may also be kept at the section house for a similar purpose.

As a general thing, however, it is best to limit the equipment to the tools actually required in every day service. Proper supplies and appliances, oil, lamps, etc., should also be furnished, and all appliances not in regular use should be kept in condition ready for service at a moment's notice. The section house, lockers, etc., should be kept locked when not in use.

The foreman should see that the tools are taken care of, and properly used, not left on or between the rails, and not used for other purposes than those for which they were intended. He should also see that all tools and appliances are clear of the track well before each train, and that the men do not wait until the last moment before quitting work in front of a train. Bars should not be thrown aside into the grass, where they are difficult to find, but should be stuck in the ground. Tools having bearings or cutting edges should not be thrown about on the ballast, where they are liable to damage by striking stones or other tools. The tools should always be taken to the section house at night, and not left out on the roadway. At the section house the tools should be placed on racks and shelves, or in tool boxes, and the sharp-edged tools kept carefully separated from the others. A little firm exercise of authority in disciplining the men as to the care and use of tools will result beneficially to the company. On a section where rocks are liable to fall, the equipment should include tools to facilitate their removal, such as rock drills or jumpers, stone wedges, blasting powder and fuse. When a special watchman is detailed to look out for a dangerous rock cut, sliding bank, etc., he should be provided with a wheelbarrow, pick, shovel, ballast hammer, two flags or lamps, and torpedoes or fusees.

Such tools as picks, bars, mauls, etc., are frequently made at the company's blacksmith shops, although they can usually be purchased ready-made almost as cheaply. The cost, however, varies with the skill of the men and the shop facilities, and whether the tools are made from new material or from the scrap heap of bridge rods, old tools, etc., always collected around a railway blacksmith shop. As a general thing, however, it is best to keep the scrap pile small and to purchase tools from reliable makers. The best design of tool should be aimed at, to secure the best service, and it is well to have as few different styles or makes of the same tool as possible. Clawbars and other heavy tools are often unnecessarily heavy, and of defective shape, while shovels are often too heavy and awkward to enable the men to do their best work with them. The use of steel instead of iron enables a considerable reduction in weight to be made without affecting the strength of the tool. The desirability of adopting standard designs of track tools has been recognized by the roadmasters' associations, and some standard designs have been officially adopted, but the actual adoption of these standards appears to make but slow progress, as individual roadmasters apparently still prefer their own familiar styles of tools, although they may have voted in favor of standard designs on general principles.

For an ordinary section gang the equipment given in Table No. 15 will be generally sufficient, but, as shown, it varies on different roads, according to the ballast and other conditions of the track. Ballast hammers, forks, etc., are not needed with gravel or soft ballast.

TABLE NO. 15.—TOOL EQUIPMENT FOR SECTION GANGS.

Article.	Railways: C.,M. & St. P.	Erie.	Ill. Cen.	N.Y., N.H. & H.
Spiking mauls ..	2 to 3	4	4	..
Ballast hammers.	..	..	6	..
Trackwalker's hammer	..	1	..	..
Nail hammer ...	1	1	1	1
Sledges	1	2	2	1
Tamping bars ..	4	..	6	8
Lining bars:				
Chisel point ...	4	3	3	...
Diamond point.	..	..	1	6
Pinch bars	..	2	3	1
Claw bars	3	5	3	3
Spike puller	..	..	..	1
Picks	6	8	6	6
Tamping picks .	6	6	6	12
Scoops	6	6	6	7
Shovels	4 to 7	6	6	12
Snow	..	..	..	5
Long-handled	..	1	1	..
Ballast forks ...	..	..	6	6
Axes	1	1	1	..
Adzes	1	2	2	2
Hand axes or hatchets	1	1	2	1
Track wrenches.	2 to 4	6	6	5
Trackwalker's wrench	..	1	1	..
Monkey wrench.	1	1	1	1
Punch	1	..	1	1
Ratchet drill ...	1	1	1	1
Brace	..	1	1	1
Auger	1	..	1	..
Files	2	1	4	2
Chisels	6	10	8	10
Hand saw	1	1	1	1
Cross-cut saw .	1	1	1	1
Scythes & snaths	2 to 4	6	4	8

Article.	Railways: C.,M. & St. P.	Erie.	Ill. Cen.	N.Y., N.H. & H.
Bush hooks	..	1	3	..
Grub hoes	..	..	3	..
Rakes	2	..	2	2
Hand car	1	1	1	..
Push car	1	1	1	1
Track jacks	1	2	2	..
Track gages ...	1	2	2	2
Center gages ...	..	..	..	1
Level board ...	..	1	1	1
Spirit level	1	1	1	..
Tie square	..	..	..	1
Rail tongs	..	3	3	4
Tape line, 50 ft.	1	1	1	1
Ditch line,100 ft.	2	..	1	1
Wire stretcher..	1	..	..	..
Padlock & chain	1	1	1	1
Oil can	2	1	1	1
Oiler	1	1	1	1
Brooms	2	2	2	4
Grindstones	1	1	1	1
Scythestones ...	2 to 4	2	2	4
Wheelbarrows ..	1	4	3	2
W. pail & dipper	1	1	1	1
Tubs	..	..	2	..
Water kegs ...	1	..	1	..
Whitewash brs..	..	2	3	..
Toolboxes	..	1	2	1
Red flags	4	4	4	3
Green flags	2	..	..	3
White flags	..	..	..	3
Lanterns: Red .	2	2	2	4
Green	..	..	..	3
White	2	4	4	5
Grn. lmp globes	2	..	..	..
Torpedoes	12	12	12	12
Shims	Yes.	Yes.	Yes.	2,000
Spike-hole plugs	Yes.	1,000	Yes.	1,000

Chicago, Burlington & Quincy Ry.

Spiking mauls	4	Punch	1	Oil can	1
Sledges	1	Ratchet drill	1	Oiler	1
Lining bar (diamond pt.)	1	File	1	Brooms	2
Pinch bar and lining bar combined	3	Chisels	5	Grindstone	1
Claw bars	3	Hand saw	1	Scythestones	2
Picks	2	Rake	1	Water box and dipper...	1
Tamping picks	3	Hand car	1	Red flags	2
Shovels	4	Push car	1	Green flags	2
Axes	1	Track jacks	2	Red lanterns	2
Adzes	2	Track gages	2	Green lanterns	2
Hatchets	2	Level board	1	White lanterns	2
Track wrench	1	Tape line, 50 ft.	1	Torpedoes	12
Monkey wrench	1	Padlock and chain......	1		

Chicago, Burlington & Quincy Ry.—This equipment is for five-mile sections on the St. Louis Division, having a foreman and 3 men. Rail-benders, cross-cut saws, scoops and wheelbarrows are kept at yards and only sent out to the sections for temporary use when needed. Tie plugs are made and sawed shims furnished in the winter if needed. For water there is made and furnished a square box of 12 gallons capacity; it is made of pine, lined with zinc (leaving ½-in. air space between wood and zinc), and has a close fitting cover. The box costs about $3, lasts from 5 to 8 years, keeps the water cool, and is much better than a bucket. A pinch bar makes an excellent lining bar, and saves the expense of the extra bars. Hatchets make good hammers. There is not much use for a spirit level except on the

level board. There should be no tools furnished to the gang, except those for use, and the list in the table is sufficient for the small gang above noted, the number of tools being increased as more men are put on.

Chicago, Milwaukee & St. Paul Ry.—This equipment is for single and double track sections, with gravel ballast. Where tamping picks are used, six are supplied. The monkey wrench is 15 ins. long. The ratchet drill has six 1-in. bits, and the auger is ¾-in. diameter. Grass or brush scythes are used as required. The oil cans are of 2 gallons capacity. The supplies also include 1 box, 1 keg of track spikes, ½-keg of track bolts, 100 nutlocks, 5 lbs. of fence staples, 5 lbs. of fence nails and 8 angle bars. The divisions are classified as far as section work is concerned: Class A consists of main lines; Class B, main lines of less importance; Class C, branches and unimportant lines where traffic is light. The accompanying list shows the equipment for a Class A section, whether double or single track. Sections of Class B or C would have only 2 tamping bars, 2 clawbars, 2 picks, 4 to 5 shovels, 2 track wrenches, 2 to 3 grass or brush scythes. The other tools would be nearly the same as on the list.

Erie Ry.—This equipment is for double-track sections with stone ballast. The sledges weigh 15 lbs. The ratchet drill has four 1-in. bits, and the brace three ¾-in. bits.

Illinois Central Ry.—This is the average equipment, varying with the character of the section. The ratchet drill has three 1-in. bits, and the brace two ¾-in. bits, while the auger is 1½ ins. diameter.

New York, New Haven & Hartford Ry.—This is the equipment for four-track sections with a foreman and nine men. No jacks are allowed, as their use on the main line is prohibited except in case of emergency, when they are handled by an extra gang. The track wrenches are of the double-end pattern. The ratchet drill has ¾-in. bits. The equipment also includes an elevation block.

Wabash Ry.—The equipment is practically the same as that of the Illinois Central Ry., but no ballast forks or spike-hole plugs are supplied.

Descriptions of Tools.

Spiking Maul.—The Pennsylvania Ry. standard spiking hammer, Fig. 148, has a head 13 ins. long, 2 × 2 ins. square at the middle, and tapering to 1⅝ ins. diameter at the ends. Its weight is 11 lbs. Another form of head has a diamond shaped center with ends of circular section tapering to 1¼ and 1⅝ ins. diameter, Fig. 149. This head is 15¼ ins. long, the lighter end being 8¼ ins. and the heavier end 7 ins. long. The head is fitted to a straight wooden handle about 3 ft. long, the end of which should be driven in at the small end of the eye in the head, and then properly wedged out.

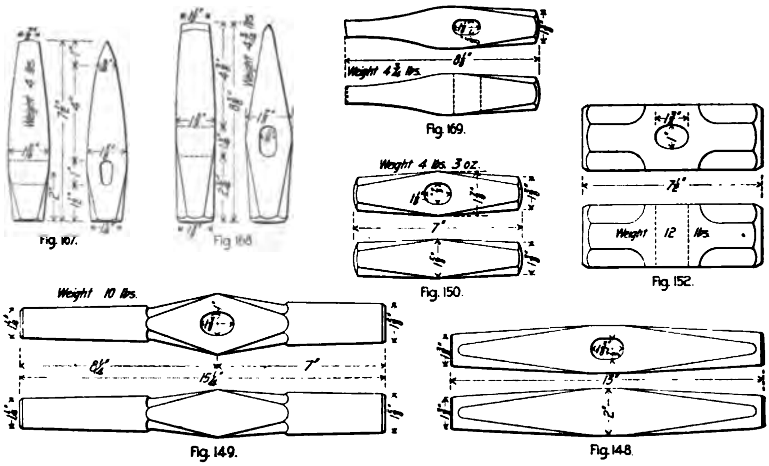
Ballast Hammer.—This is for breaking stone ballast, and the Pennsylvania Ry. has two forms of ballast or napping hammers, Fig. 150. One weighs 3 lbs., and is 6½ ins. long, with octagonal ends 1¼ ins. diameter; the other weighs 4 lbs. 3 oz., and is 6¾ ins. long, 1½ × 1¾ ins. at the middle and 1¼ ins. diameter at the ends.

Trackwalker's Hammer.—This is shaped like a locomotive coal pick, Fig. 151. The head is about 12 ins. long and has one end octagonal and the other curved to a chisel edge 1½ ins. wide. The weight is about 14 lbs.

Sledge.—This is a short heavy hammer head set on a long, straight handle. The head, Fig. 152, is about 7½ ins. long, octagonal, with circular

ends 2½ ins. diameter, and weighs 12 to 14 lbs. It is used for knocking out ties and for striking track chisels, and foremen should see that spike mauls are not used for such purposes.

Tamping Bar.—For tamping ballast (except stone or slag) under the ties, a bar is used about 5 ft. 6 ins. long, and weighing about 13 lbs. Two forms are shown in Figs. 153 and 154, the latter being the form adopted



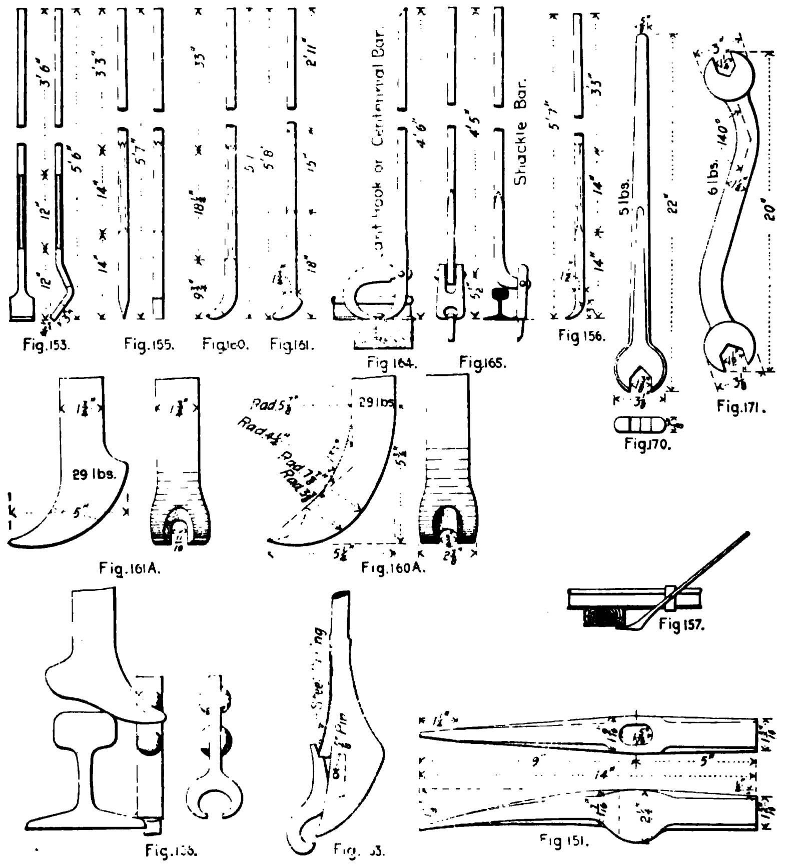
Track Tools.

as standard by the Roadmasters' Association of America. The bar is generally of ⅞-in. round iron, straight, with a flat piece 6 ins. long and 4 ins. wide, ½-in. thick at the edge, welded on at an angle of 24°, so as to strike well under the tie. The upper end should be flattened to a chisel edge 2 ins. wide. Some bars have the lower end bent, made ⅞-in. square, and having a tamping head 3½ ins. wide and ¾-in. thick. A larger diameter is sometimes preferred as giving a better grasp for the hand, and in some cases a gas pipe handle is used to increase the diameter without increasing the weight.

Lining Bar.—The bar used in lining and throwing track is a straight bar, Fig. 155, generally about 5 ft. 6 ins. long, weighing 22 to 30 lbs., and tapering from 1½ ins. square at the lower end to ⅞-in. diameter at the top. A weight of about 24 lbs. is sufficient in a well made bar. The smaller end should be formed with a sharp diamond point, and the square (or lower) end should have a 1¼-in. chisel edge for about 3 ins. In throwing track the flat end of the bar is driven into the ballast (but not at too great an angle or it will raise the track in throwing), and two men can take hold of it. In some cases the pinch bar serves as a lining bar, as it answers very well for the purpose and thus saves the expense of the extra bars.

Pinch or Raising Bar.—This is used for heavy lifting and prying up, and for raising and holding a tie for spiking or for slight raising of track, raising low joints, etc., although on some roads the track jack is used even for raising track very slight amounts. The bar, in Fig. 156, is 5 ft. to 8 ft. long,

weighing 26 to 40 lbs., and tapering from 1½ or 1⅝ ins. square at the lower end to ⅞-in. or 1-in. diameter at the top. The lower end is chisel shaped for about 3 ins., but sometimes the front face is vertical, only the back face of the chisel edge being inclined, while in the lining bar, Fig. 155,



Track Tools.

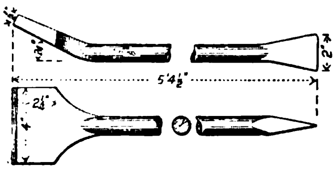
both faces are inclined. The end of the pinch bar is sometimes straight, but is more useful when slightly curved outward so as to get a good hold, and form a fulcrum when prying.

Holding-Up Bar.—In spiking rails it is customary to hold the tie up to the rail by a bar (or two bars) placed under the tie end, the holder-up either pulling up on the bar, or using a block for bait and bearing down on the bar. This work is usually very ineffective, as in the former case the bar will sink in the ballast, and in the latter case much time is wasted in getting and setting the "bait" block; while the man will allow the bar to "give" every time a blow is struck on the spike. A handy tool which effects a considerable saving of time and labor in this work is a holding-up

bar, Fig. 157. This is a pinch-bar with an inclined sharp, chisel-edged lower end to fit under the tie, or to bite into its side. To one side of the bar is pivoted an angle shaped piece, the horizontal part of which bears on the top of the rail, the bar being parallel with the rail. When the holder-up bears down on the end of the bar (which is parallel with the rail), he presses the tie up and the rail down, thus holding them firmly for the spiker. A shovel should never be used for holding up ties.

Bridge Bars.—Special bars are used for bridge work and two of the forms used on the Illinois Central Ry. are shown in Figs. 158 and 159. The former is a timber bar, for sounding and moving timber. The latter is for

Fig. 154.—Tamping Bar.



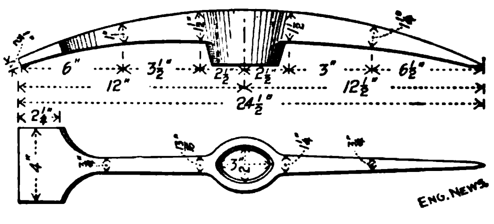


Fig. 174.—Tamping Pick.

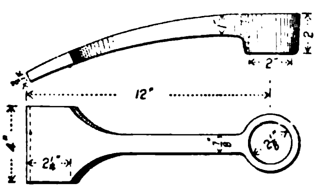


Fig. 175.—Tamping Puddle.

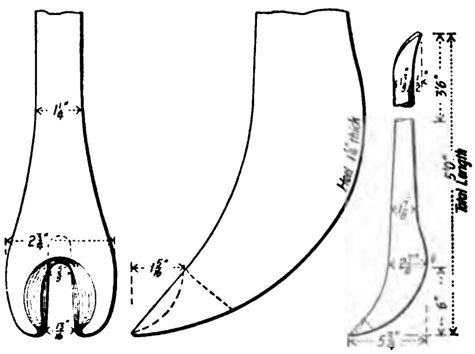


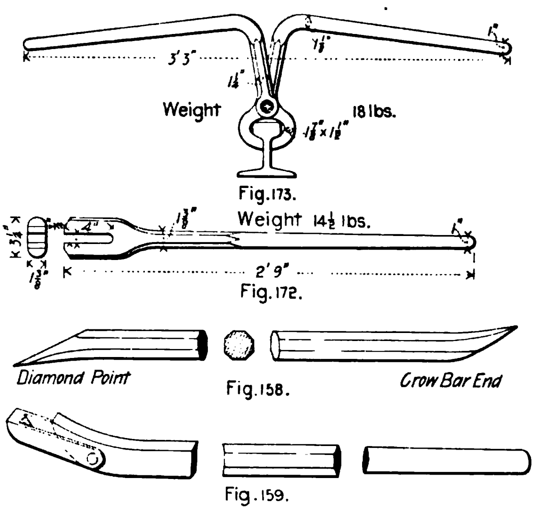
Fig. 162.—Clawbar.

Standard Forms of Tools Recommended by the Roadmasters' Association of America.

pulling out headless drift bolts, the shackle being slipped over the bolt and a bait block put under the heel of the bar to act as a fulcrum.

Clawbars.—For pulling spikes, a clawbar is generally used, averaging 5 to 6 ft. in length, and weighing from 25 to 30 lbs. It is made in a variety of patterns, the body of the bar being usually about 1¾ ins. square at the ends, then 1¾ ins. octagonal and then of circular section tapering to 1-in. diameter at the top. Three forms of clawbar are shown in Figs. 160, 161 and 162. The lower end is curved outward at an angle of about 45°, and has a broad chisel edge with a notch to take the neck of the spike, the edge being struck under the back of the spike head. The distance from the point of the claw to the back of the bar is about 4 ins.. and a block or "bait" is put at the back to serve as a fulcrum. Sometimes the back of the bar has a curved projection or heel to

avoid the use of "baft," the distance from point of claw to back of heel being about 5 ins. Another form of bar, known as the "bull-nose" bar, has the lower end curved outward for a height of 6 or 8 ins., the radius being 5 or 6 ins. and the distance from edge of claw to back of bar being 4 to 6½ ins. The "gooseneck" clawbar has the lower end bent backward and then forward again in a reverse curve so as to give a long leverage in pulling, but as the claw is then nearly flat or at right angles with the bar, it cannot be struck under the spike head so well as a claw of 45°. For this reason it is best to use both kinds if much spike pulling is to be done, using the straight bar to start the spikes and the "gooseneck" bar to pull them out.



Track Tools.

In this way two men can do more work and injure fewer spikes than one man with a straight bar, and another man to hold "bait." The clawbar adopted by the Roadmasters' Association of America, Fig. 162, is 5 ft. long, weighs 30 lbs. and has a curved chisel point at the upper end. The claw end has a spread of 5¾ ins. from point to back of heel, 6 ins. above the point. In using these bars care should be taken not to bend the spikes, a matter which is very often neglected by the foreman. If the spike is so driven that it is difficult to get hold of the head with the clawbar, it is better to chop away the wood with the sharp end of the bar, than to hammer the back of the claw to force it onto the spike.

Spike Pullers.—For pulling spikes in such places as on elevated railways, where the guard rails prevent the use of the ordinary clawbar; or at frogs and switches, on bridges and at stations, where these bars cannot well be used, a special form of bar or a special spike-puller must be used. Fig. 163 shows a bar used on the Chicago & South Side Elevated Ry. (whose track cross section is shown in Fig. 94), this bar having a loose hinged tongue and being worked parallel with the rails. The Manhattan Elevated Ry., of New York, uses two forms of bars, as shown in Figs. 164 and 165. The shackle bar was devised by some of the employees and

works very satisfactorily, the bar resting on the top of the track rail, as shown. The Verona spike puller, Fig. 166, has a rigid jaw which is slipped under the sides of the spike head, and a vertical stem on the jaw has two balls or projections to give a grip for a heeled clawbar, the heel of which rests upon the rail. This device weighs about 1 lb. and is manufactured by the Verona Tool Works, of Pittsburg. The Prout spike puller consists of a heeled bar with two loose claws hanging in front to catch the sides of the neck of the spike, while a bearing piece at the back rests on the tie and forms a bearing for the curved heel of the bar which rests on the rail head. A spike puller used in India works on the principle of the rail tongs, the short handles fitting into holes in the forked end of a bent bar which rests on the rail head. These devices are simple and inexpensive tools, but effect a great saving of time and labor, especially in large yards.

Chisels.—Cold chisels used for cutting steel rails must be of good material, well made and well tempered, if they are to do much work. If too hard, they will break in use, especially in cold weather; while if too soft, they soon become dull and blunt. In winter it is well to warm them before using, and to strike the first few blows lightly. When only slightly dulled, and retaining their temper, they may be sharpened on the grindstone, but otherwise they must be sent to the shop. A good chisel should cut three or four rails, and the work should be done carefully, so as to damage the rail as little as possible. It is very bad practice to notch the rail with a chisel and then drop it on a block to break it, but sometimes the head is cut with a portable saw and the work finished with the chisel. Two forms of chisels are shown in Figs. 167 and 168. The track chisel adopted by the Roadmasters' Association of America, Fig. 168, is 8⅝ ins. long and weighs 4¾ lbs. The eyehole is 11-16 × 1¼ ins., and the head extends beyond this 4⅝ ins. on the cutting side, and 2¾ ins. on the striking side. The cutting edge is 1⅛ ins. deep. The back end is octagonal, with a rounded and slightly spherical face 1⅝ ins. diameter. The sides of the cutting head are flat, but in some chisels they are curved or swelling. The handle should be about 18 ins. long, so that the man holding it will be out of the way of the striker's hammer. A properly made and fitted handle should be used, and not merely any kind of a stick that is available.

Axe and Adze.—These are too familiar to need any comment except as to the economy of good materials. They should be kept sharp, and should be used only for their proper purposes, the axe for splitting and chopping only, and the adze for trimming ties or other timbers.

Saws.—These also are tools familiar to all workmen. Hand and crosscut saws and other edge tools should have their teeth or edges protected from damage by striking other metal tools. In using crosscut saws the men should stand opposite each other, and pull on the saw, never pushing it.

Punch.—The steel track or rail punch for hand use, shown in Fig. 169, weighs about 4¾ lbs. The head is usually 8⅛ ins. long, 1⅝ ins. diameter at one end and 11-16-in. square at the other, the latter having a beveled face.

Wrench.—The ordinary track wrench is usually a steel die forging, about 22 ins. long, weighing 5 lbs. The handle is of 1-in. diameter, having one end flattened out for the jaw, and the other end shaped to a chisel edge or

tapered to ½-in. diameter to put through the holes of rails and splice bars to bring them together. The jaws should have four sides, to conform in shape to a hexagon nut, and to fit a square nut. Figs. 170 and 171 show an ordinary and a double-end or S-wrench. Long-handled wrenches are sometimes used, but with a handle more than 26 ins. long a careless man can apply such force as to strip the threads of the nut or bolt.

Rail Fork.—This resembles a long wrench, but with a slot or notch ¾ × 4 ins. (instead of a jaw) in the flat end. As shown in Fig. 172 it is 2 ft. 9 ins. long, with a handle 1 to 1⅜ ins. diameter, and weighs about 14½ lbs. This tool is used for carrying and handling rails.

Rail Tongs.—These are used for carrying rails, and have handles of 1⅛-in. round iron or steel, with jaws about ⅞ × 1½ ins., on the ends. The tool shown in Fig. 173 is 3 ft. 3 ins. long, the handles 1 to 1⅛ ins. diameter, and the weight is about 18 lbs.

Pick.—Ordinary picks have heads about 2 ft. 2 ins. to 2 ft. 6 ins. long, weighing 7 lbs., and are fitted with straight wooden handles about 3 ft. long. The best picks have heads of solid cast steel, which will not split in the eye, but those made in railway shops are usually of iron, with cast steel ends welded on. The best refined iron should be used. For a clay pick, the arms are 1½ ins. deep and 1 in. wide next to the eye, and one end is pointed, while the other end has a chisel edge 1⅛ ins. wide. The patent "eyeless" pick (Eyeless Tool Co., New York), is made of a steel bar having a malleable iron socket at the middle to which the handle is attached by a bolt. There should be three picks to every two men in the gang, to allow of their being sent to the shops for repair.

Tamping Pick.—This is used for tamping stone and slag ballast, and resembles the ordinary clay pick, except that while one end is pointed the other end has a flat piece or tamping head about 2¼ ins. long and 4 ins. wide, with which to drive the ballast under the ties. A steel head 24½ ins. long weighs about 8½ lbs. Fig. 174 shows the form of tamping pick adopted as standard by the Roadmasters' Association of America. In another form the tamping end has the head gradually widening to shape from the eye, instead of having the plain shank with tamping head.

Tamping Puddle.—This is used for tamping gravel, cinders, sand and dirt ballast, and resembles the half of a tamping pick, the weight being about 5 lbs. The form adopted by the Roadmasters' Association of America, and shown in Fig. 175, is 12 ins. long from center of eye to edge, the shank being ⅞-in. wide, and tapering from 1 in. thick at the eye to ½-in. at the edge, which is 4 ins. wide for a length of 2¼ ins. The eye may be circular or oval.

Shovels.—These are of various patterns, for tamping and ditching, and for handling gravel, cinders, snow, etc. A weak point in welded and unwelded shovels is a lack of strength in the straps immediately above the blade, and a tendency to break from the top of the blade downward. A good shovel is made from one piece of crucible cast steel, No. 12 gage, properly tempered, and having the straps strengthened by a socket for the handle extending about 2 ins. above the blade, making a much stronger connection than the straps alone. The top should also be reinforced or strengthened to prevent the breaking or splitting of the blade. Tamping shovels, Fig. 176, have blades approximately square and flat, about 10 ins. wide and 12 ins. deep. The handle is about 30 ins. long, and the total

weight of the shovel about 7 lbs. In sand and gravel ballast the sectionmen will often tamp with the handles of their shovels instead of with the tamping bars, thus wearing and breaking the handles. The Shaw combined shovel and tamping bar was invented to provide for this practice, and has an iron shield over the wooden handle. Tamping shovels with malleable iron heads on the wooden handles are also used occasionally.

The St. Louis Shovel Co.'s tamping shovel, Fig. 176, has the socket for the malleable iron handle closed at the upper end, thus holding the handle firmly in place when used as a tamping bar and lessening the danger of bursting the socket when the handle is thus used. The shovel is of cast steel with a taper socket strap.

Fig.176. Fig.177.

Fig. 176.—Tamping Shovel.
Fig. 177.—Scoop.

A worn shovel may have its edge sharpened and be used for cutting weeds. Scoops, Fig. 177, are large full shovels for handling coal, cinders, snow, etc. For digging post holes, long-handled shovels are used, having straight handles 4 ft. to 4 ft. 6 ins. long. Post-hole augers may also be used by a fencing gang. Special forms of long-handled shovels are used for deep holes for telegraph poles, and various forms of ditching spades are also supplied where there is much work of this character. Large flat wooden shovels are convenient for handling snow in yards.

Forks.—For handling stone or slag ballast it is well to use forks (like stable forks), having eight to ten tines or prongs, as this will eliminate the dirt or fine material which would be put into the track if shovels were used. The New York, New Haven & Hartford Ry. uses eight-pronged forks for handling stone ballast, furnishing one to each sectionman, an ordinary square-point shovel being also furnished to each man for handling the finer stone and for ditching, etc.

Scythes.—For clearing the right-of-way, etc., scythes and special tools are necessary, according to the material to be dealt with. The railway scythe for cutting coarse grass and light weeds, is slightly heavier than the common grass scythe, which is too light for this work; and it may be tightly fitted to an ordinary snath or handle, or to the brush snath, which has not quite so much curve. The bramble scythe is still heavier, and is used for cutting brambles and strong weeds, while the shorter and stouter brush scythe is used for brush and young bushes. Both of these latter should be fitted to brush snaths.

Bush Hook.—This is a stout, sharp, straight blade with a curved end, used for cutting bushes, and is fitted to a straight axe handle.

Hoes.—The grub hoe is a very useful tool in cutting roots, grubbing heavy sod, etc., preparatory to new work, and is also handy in ditching and for removing tough grass and weeds from the side of the track. It is about 16 ins. long, with two 3¼-in. cutting edges, one horizontal like an adze, the other vertical, like an axe. The head weighs about 5 to 6 lbs., and has an eye in the middle to which is fitted a straight wooden handle. Long-handled weed hoes are advisable where much weed cutting has to be done, being operated more easily than a shovel and saving much backache, thus enabling the work to be done quicker and to better advantage. This tool resembles a garden hoe, with rather long blade, set at an angle of about 150° with the handle.

Rakes.—These are ordinary heavy garden or farm rakes for clearing up brush on the right-of-way, trimming station grounds, etc. Wooden hay rakes may be used if the company makes hay from grass on the right-of-way.

Brooms.—Ordinary flat brooms are used for clearing snow from switches and frogs, cleaning ties after adzing for relaying rails, and also for keeping the section house clean.

Track Gage.—Home-made wooden gages are used on nearly every road, and have the advantage over iron that they are not appreciably affected by temperature, and are not liable to become bent (and therefore inaccurate). On the whole, however, the iron gage is probably preferable. The wooden gage may have a rod of seasoned oak or ash 1¼ × 1¾ to 1½ × 2 ins., with iron lugs secured by screws. The Huntington gage, which is very extensively used, has a wrought iron tube with a double bracket at one end and a single bracket at the other end, these brackets being of malleable iron, screwed on with a taper thread and secured by rivets. The double bracket is set to the gage rail, and acts as a square to insure the rod being set at right angles across the track. In the Caffery gage, invented by Mr. R. Caffery, General Roadmaster of the Lehigh Valley Ry., the iron ends are connected to a wooden rod or bar and have lugs 1⅜ ins. deep and 1¾ ins. wide, the distance between the inner faces forming the guard rail gage. One of the lugs has on its top a rack with V-shaped teeth fitting into recesses in the lower face of the iron end of the bar. This lug is held by a thumbscrew and may be shifted to give the proper widening or tightening of the gage. The "Circular" gage consists of an iron or wooden rod having at one or both ends an iron bracket formed as a segment of a circle of which the diameter is equal to the gage between the rail heads, so that the gage distance will be correct whether the rod is applied at right angles or obliquely across the track.

On roads having a track circuit for a block-signal system, metal track gages cannot be used, as they short-circuit the current and affect the signals in the same way as the wheels and axles of a train. This has led to a more extended use of track gages with wooden bars, but of better construction than many of the old wooden gages used on minor roads. In Fig. 178 is shown a gage of this kind having steel ends securely riveted to a white oak bar 1¼ ins. square. To insure greater rapidity and accuracy in testing the gage of track than can be insured with a single lug on each end, one end of the gage has a steel fork with two lugs, so that by holding the fork with both lugs bearing against the gage or line rail, the bar will be truly at right angles to this rail, and the other lug will give the accurate

gage between rails. The same cut also shows an all-metal gage having a bar of 1-in. gas pipe, shrunk upon steel ends and riveted to them. The gage with the wooden bar weighs 8½ lbs., and that with the iron bar weighs 12 lbs.

Track Level.—This tool is for ascertaining whether the opposite rails are in the same horizontal plane on tangents, or whether the outer rail has the proper elevation on curves. The ordinary track level or level board is a board about 5 ft. 6 ins. to 8 ft. long, and 1¼ to 1½ ins. thick, with a handle or hand-hole, and having a spirit level let into the top or side. One end is made with steps or offsets whose

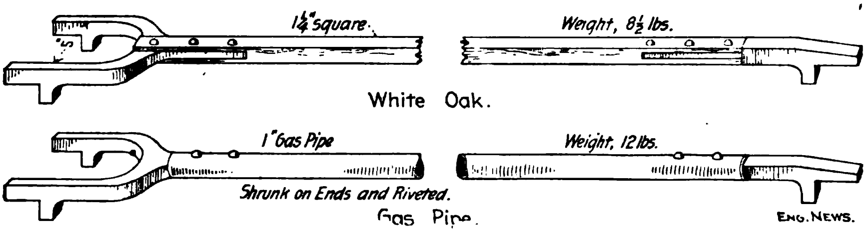


Fig. 178.—Verona Wooden and Iron Track Gages.

depth is equal to the elevation of outer rail for curves of different degrees, the spirit bubble being level on a curve when the bottom edge of the board is on the inner rail and the offset of proper elevation is on the outer rail. The gage of this style used on the Buffalo, Rochester & Pittsburg Ry., is shown in Fig. 179. The board is 5 ins. deep for a length of 5 ft. 6 ins., and then stepped off in offsets ½-in. high and 2½ ins. long, giving an elevation of 1 in. per degree up to and including 5°, and then ½-in. per degree up to a maximum of 7 ins. The offsets and the other end of the board are shod with brass. The board is lightened by three openings about 12 x 5 ins., and has a spirit level at each end. Mr. Hoyt, Chief Engineer, suggests that the board might be 7 ft. long, with seven

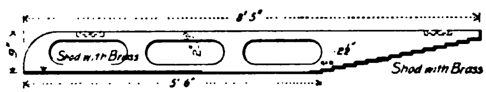


Fig. 179.—Track Level and Gage; B., R. & P. Ry.

1-in. offsets 2½ ins. long, to be used with a ½-in. shim of metal carried by the foreman and placed on the rail when the curvature varies by half degrees. The McManus track gage and level has a wooden rod with iron brackets, and a vertical rod passing through one end is held at any desired height by a pin passing through holes spaced according to the amount of elevation, the head of the iron rod being set on the inner or lower rail of the curve. The Verona combination level and gage has a bar of well seasoned white pine, 1½ x 3½ ins. at the middle and 1½ x 2 ins. at the ends. The ends are protected by steel straps 3-16-in. thick, the under part of the strap being flat (for a level only) or bent to form the lugs for a combination level and gage. A vertical steel rod or bar, ½ x ½-in., passes through one end of the bar and is graduated to quarter inches on two sides. This rod

is held by a horizontal thumbscrew in the end of the bar, which has a pointed end engaging with holes ¼-in. apart in the rod. The rod has a flat foot 3 x 1½ ins., to give a firm seat on the rail head. Guard rail lugs can be fitted if desired.

A very excellent form of level board, which is also at once a track gage, guard-rail gage and track level, is shown in Fig. 180. It is a wooden board 1 x 4 ins., faced with an iron strip 3-16-in. thick extending over the bottom edge, gage lugs and ends, and secured by screws. The length over all is 5 ft. 5½ ins. The gage of track and guard rails is measured respectively over the outside and inside of the lugs, as shown, the lugs being 2 ins. deep and 1⅞ ins. to 1⅝ ins. wide. At the middle of the board is a hand-hole, with a spirit level tube set in the lower seat. At one end of the board is a plate sliding vertically in dovetailed guides, and held at any position by a nut on a ⅜-in. bolt. A graduated scale is marked on the slide, and in testing the superelevation of curves the slide is lowered to the amount of elevation required, this end of the level being then placed on the inside or low rail, and the outer rail then raised or lowered until

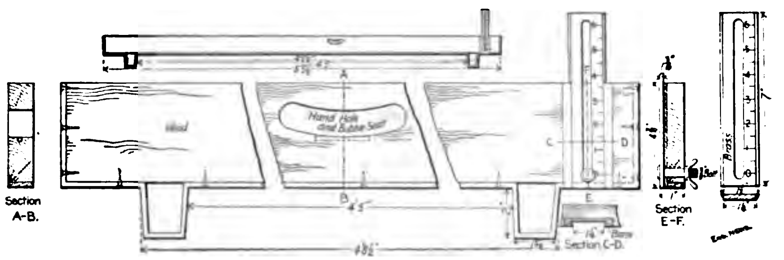


Fig. 180.—Track Level and Gage; W. Va. & P. Ry.

the spirit level-bubble is in the center of the tube. By the attachment of a straight rod 3½ ft. long, held in position at the gage line by a semi-circular arc, this tool is a great assistance in lining tangents. By making the iron strip in two pieces, separated by a space of about 2 ins. at the middle, the tool is sufficiently insulated to enable it to be used on roads having automatic signals operated by track circuits. The device was designed by Mr. J. W. Galbreath, Chief Engineer of the West Virginia Central & Pittsburg Ry., specially for the use of the track supervisors, but it was found to be so useful that it was made in somewhat lighter form and put in the hands of all the section foremen.

Leveling Boards.—These are used for sighting when raising or surfacing track or taking out sags in the grade line. In some cases three blocks of the same thickness are used, placed on the rail at the point to be raised and at the already surfaced portion on each side. A better plan is to have a white board (having a black stripe a little above its center), and two blocks, each as high as from the bottom of the board to the top of the black stripe. The board is placed across the rails at a point where the track is at proper grade. One block is placed on the rail at the point to be raised, and the other the foreman places on the rail at a point already at grade. The track is then raised until the middle block is sighted in line with the top of the first block and the stripe on the board.

Rail Benders.—Until recent years, rails have been bent by various rough

methods, but there is a growing recognition of the necessity and advantages of doing this work accurately and without injury to the rail. It is very bad practice to bend rails by hammering them with sledges, or by dropping them on blocks, as such methods are more liable to kink the rail than to give it a uniform curve. Rails should never be nicked with a chisel for bending or straightening. In bending by the use of a curving hook and track lever, the rail is laid on its side, with its ends resting on two ties placed across the track rails, and the track lever is placed on the rail with its toe engaging a hook placed under one of the track rails. By bearing down on the free end of the lever the rail is bent as desired. Rail bending machines should be used for all rails to be bent to curves of over 3°. The ordinary jim-crow rail bender, Fig. 181, has a curved frame with hooked arms to hook over the rail head or flange, and pressure is applied to the rail head between the arms by a screw which is turned by a long handled wrench or by a bar fitting into the holes of a capstan-headed screw until the ordinate for the required curve is reached, when the screw is slackened, the machine shifted along the rail, and the operation repeated.

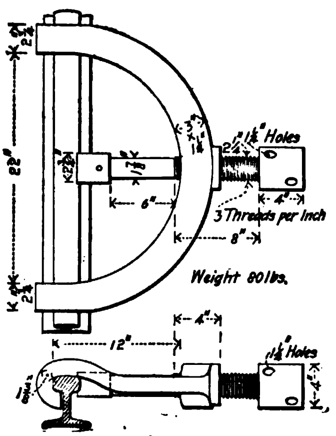


Fig. 181.—Rail Bender.

These machines are of various patterns, and weigh from 150 to 200 lbs. One of the best forms is the roller rail bender and straightener, as shown in Fig. 182, having grooved rollers on the arms to fit the outside of the rail head, and a third roller on the bending bar to fit against the inside of the rail head. The rail is first bent in the usual way, by setting up the screw with a long wrench until the middle ordinate for the desired curve is obtained; then the inner roller is turned by a long lever or a cross-handle wrench, causing the machine to travel along the rail, thus giving a uniform curve from end to end. To straighten a rail, the machine is put on the outer side of the curve. The number of men required depends upon the weight of rail and the degree of curvature. In some rail benders the power is applied by an eccentric or cam, thrown by a long lever working in a vertical plane at right angles to the track. Hydraulic rail benders resemble the jim-crow in general form, but have a vertical hydraulic cylinder at the back of the frame operating the ram or plunger, which bears against

the rail head. The ram may be run in and out for a few inches by hand, without pumping, thus allowing the machine to be readily placed on the rail and the ram brought up to its work, when a few strokes of the pump bend the rail to its desired curvature. The pressure is then reduced and the rail slid along for another application. The ram is graduated to show the extent of the bend and may have a loose head shaped to fit the rail head. The weight is from 200 to 275 lbs., and while this is more than the common screw bender the machines are compact and readily handled.

Track Lever.—The track lever, Fig. 183, was the usual means of raising

Fig. 182.—Roller Rail Bender.

track until track jacks became of general application, and it is still used to some extent. It consists of an oak pole 9 to 10 ft. long, about 6 x 4 ins. at one end, and 2 ins. diameter at the other end, the larger end being fitted with an iron shoe and with a ring for carrying. The shod end is put under the rail or tie and blocking placed under it, and then two or more men bear down on the free end. The method is clumsy and inefficient as compared with the use of jacks, as it requires several men to work it, raises the track by jerks, and makes it difficult to adjust the amount of rise accurately, and even when the proper rise is obtained at least one man must hold the end of the lever until the ties are tamped, and he generally slacks up on it in spite of all care.

Track Jack.—There are numerous varieties of track jacks, operated by ratchets, screws, friction clutches, hydraulic power, etc., and different

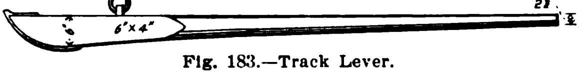


Fig. 183.—Track Lever.

makes of these varieties may be found on most roads, while each roadmaster and foreman has a preference for some particular make. A good jack must be able to sustain a heavy weight on the lifting bar, be positive in action, durable in design and capable of being relieved quickly of its load and removed almost instantly. For ordinary work they are about 24 to 30 ins. high, 7 x 12-in. base, with a rise of 12 to 15 ins., capacity of 8 to 15 tons, and weigh about 60 to 75 lbs. The lighter they are the better, as

long as they are of sufficient strength. One of the best forms of ratchet jacks is of the compound lever pattern, with two pawls (one of which is always engaged); it can raise or lower its load half a notch at each stroke, while it can be instantly relieved of its load. It may lift the head with the down motion of the lever only, or with both up and down motion. One form of screw jack has a horizontally revolving handle at the top, but a better arrangement is a ratchet lever working either vertically or horizontally, like the lever of a track drill. Hydraulic jacks are also used, and are generally filled with 2 parts alcohol to 3 parts water in winter, and 1 part alcohol to 4 parts water in summer. Water or kerosene should not be used, as water will cause rust and may freeze, while kerosene destroys the packing. As track jacks are too high to go under the ties they lift by means of a claw hung from the head of the lifting bar, the claw being close to the bottom of the jack when lowered. The jack

Fig. 184.—Jenne Track Jack.

therefore reaches above the rail and may be a dangerous obstruction to trains, for which reason it should be made to release as promptly and easily as possible. The Fisher jack, however, is entirely below the rail, and is therefore a very safe form of jack. It acts on the principle of a toggle, being worked by a lever turning a horizontal right and left hand screw (parallel with the rail) which passes through the lower ends of the toggle arms, while the upper ends (or apex of the toggle) carry a bearing plate which forms the seat for the rail or tie. This jack has a base of about 16 x 5½ ins., weighs 30 lbs., has a capacity of 15 tons and is only 7 ins. high at its lowest position. In the Jenne jack, Fig. 184, the link at the end of the working lever is coupled to a friction collar or ring, which grips the bar or stem of the lifting claw. The upper ring encircling the bar is known as the lifting ring, and the lower one as the retaining ring. The holes through them are bored at an angle, so that when horizontal they

grip the bar, but when lowered they release it. These jacks for heavy ballasting, surfacing and general track repairs, have a 15-in. lift, and a capacity of 10 tons, the jack being 35 ins. high when lowered, and weighing 90 lbs. A smaller size of the same capacity for short and heavy lifts in surfacing has a 7-in. lift, is 22 ins. high, and weighs 55 lbs. For light surfacing the jack has a capacity of 5 tons, a lift of 12 ins., is 31 ins. high, and weighs 60 lbs. The load can be lowered instantly or slowly. These jacks are manufactured by Pettibone, Mulliken & Co., of Chicago.

One of the latest forms of ratchet jacks put upon the market is the Verona ratchet jack, shown in Fig. 185, which has been designed to com-

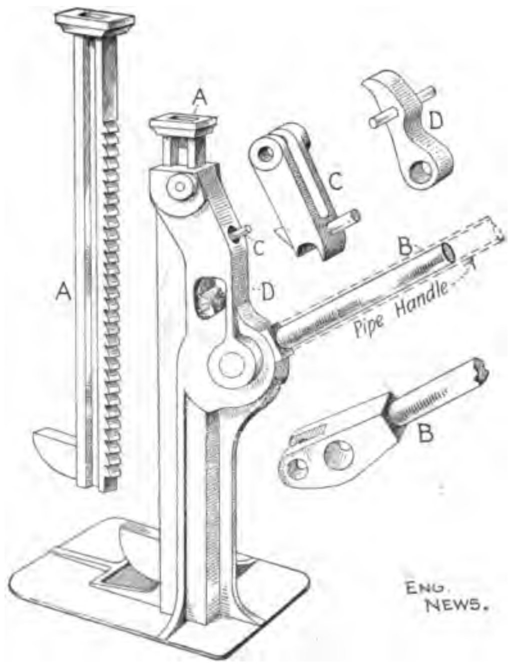


Fig. 185.—Verona Track Jack.

bine lightness with strength and easy working. The frame is of malleable iron, with a base 7 x 12 ins., as recommended by the Roadmasters' Association of America. All the other parts are of crucible steel, with the exception of the loose pipe handle, which can be fitted to the lever. The rack bar, A, has a sectional area of 1½ sq. ins., and is operated by the lever B and pawl D, while the top catch, C, holds the bar in position at the height at which it is set. The load can be let down one tooth at a time when required, and can be dropped instantly and with certainty by the lower pawl, no independent trip being required. The jack is 21 ins. high, and has a lift of 14 ins. All the working parts are strong and simple in construction, and the jack weighs only 51 lbs., while its lifting capacity is 10 tons. It is manufactured by the Verona Tool Co., of Pittsburg.

Track jacks are very important, useful and labor-saving tools, and one

man with a jack can raise track better and more accurately than three men with a lever, while the jack holds the track steady and does not slack down. When it is once set, the entire gang can be at work tamping, though where there is much traffic it is best to keep one man permanently at the jack, especially on double track (unless the Fisher jack is used). On many roads the jack is now used instead of the raising bar for small rises, as in surfacing, etc., as well as for large lifts in raising lengths of track, while on other roads it is used only at frogs and switches, and for rises of over 3 ins. The best practice is to raise both sides of the track simultaneously by the use of two jacks, and in general the claw should be placed under the tie and not under the rail, as in the latter case it tends to loosen the spikes. The jack should never be set on the inside of the rail, as in such position it is liable to derail a train, as was the case in the accident at Quincy, Mass., on the Old Colony Ry., in 1890, in which 23 persons were killed or fatally injured, and about 30 were more or less injured. The pilot of the engine caught the jack and threw it across

Fig. 186.—Ball Track Drill.

the rail. If set outside the rail the man in charge is in less danger, and less likely to forget to release and remove the jack when a train approaches, while even if the jack should be in place the engine would knock it away from the rail. The rules of some roads require that the jack shall always be used on the outside of the rail, no excuse being accepted for contrary practice, while the New York, New Haven & Hartford Ry. goes to the extreme of not issuing jacks to the section gang, but having an extra gang to do all work requiring the use of jacks. Where much lifting is going on, flagmen should be sent out to warn trains to run cautiously.

Track Drill and Punch.—Ratchet drills with automatic feed are generally used for drilling bolt holes in the rails, and in some of the various patterns several holes can be drilled at one setting of the clamp, the drill sliding along the frame, as in Fig. 186. The clamp should fit over the flange and not over the head of the rail, so as not to offer any obstruction to trains, and the drill carrier should

slide on the frame so that the four or six holes of a joint can be drilled at one setting of the frame. In the Schuttler continuous acting ratchet drill the tool revolves with the movement of the operating lever in each direction, instead of in one direction only, as in the ordinary drills. The bits or drills should be handled carefully. In using the tool, the frame is put in position, the point of the feed screw put on the steel center, and the feed wheel then turned with the pin until the bit strikes the rail; then the automatic feed is turned down in place, feeding the drill positively and regularly as the lever is worked to and fro. Portable hydraulic punches are used to some extent, the jaw fitting over the rail and having at its back a vertical hydraulic cylinder operating the horizontal punch. An adjustable guide at the top of the jaw insures all

Fig. 187.—Bryant Portable Rail Saw.

holes being punched at the same height in the same size of rail. These machines weigh from 200 to 300 lbs. A vertical hydraulic punch for punching spike slots in rail flanges weighs about 90 lbs.

Rail Saws.—Rails are generally cut by means of a cold chisel and hammer, and too often they are partly cut and then broken by dropping them on a block, resulting in a rough and irregular rail end. Portable rail saws clamped to the rail are now being more generally used, and do better and quicker work, cutting a heavy rail in from three to ten minutes. The Higley machine and the Bryant machine have circular saws operated by hand cranks and gearing, the saws being 14 to 20 ins. diameter. The former weighs 150 lbs. The latter, shown in Fig. 187, is made by the Q.

& C. Co., and weighs about 290 lbs. A good thin oil, such as lard oil, is recommended for lubricating the saw of the Bryant machine. The Smith machine (made by Manning, Maxwell & Moore) has a frame about 3 ft. high, with a reciprocating saw blade worked by two levers like a fire pump or hand car. Its weight is about 120 lbs., and soapsuds are recommended for lubricating the saw, no oil being used in any case on the saw. With these machines very clean cuts are made and very thin pieces can be cut when necessary. Their use is particularly advisable on first-class track, for heavy rails and in fitting up frogs and switches. The Ehrhardt machine has a circular saw driven by a hand crank and gearing, but weighs 1,100 to 1,400 lbs. Its frame may be fitted also with a drill press for bolt holes and mounted on a four-wheel truck. It is therefore more adapted for use in fitting up yards, etc., where rails have to be cut to various lengths. The machine is, however, also designed to be clamped to the rails in the track, but weighs 1,200 lbs. It is built by Gustave Ehrhardt, of Pittsburg.

Hand Cars.—These are sometimes made at the company's shops, but as

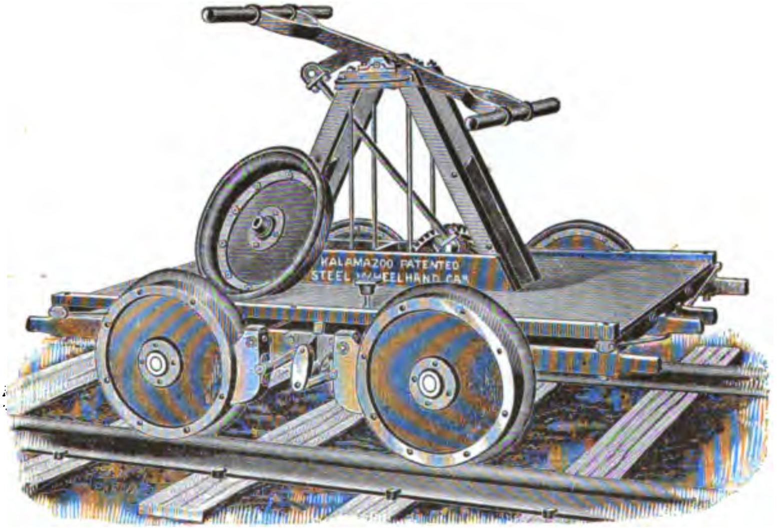


Fig. 188.—Hand Car.

a rule it is better to purchase them from firms making a specialty of their manufacture. They should be kept in good order, oiled frequently with a little oil, and taken off the track when not in use. When badly out of order they should be sent at once to the shops for repair, so as not to compel the men to expend unnecessary work in propelling a hard-running car. Most roads forbid their use for carrying rails, except in case of emergency. The cars should be as light as possible, consistent with strength and durability, may have wooden wheel centers, or pressed steel wheels, and should invariably be fitted with a strong brake gear, generally operated by the foot. Steel wheels are best for durability, but wood-centers are required on lines where a track circuit is used, to prevent the cars from operating signals in the same way as a train. The cars will ride

more easily if one of the wheels (not on the driving axle) runs loose on the axle. Oil boxes should be frequently repacked, as the packing soon collects grit and sand, but roller bearings on the axles make the cars easy to propel. The average size of car has a platform 6 ft. to 7 ft. 6 ins. long and 4 ft. 6 ins. wide, with a floor of matched planking and the ends of the sills extended to form handles. The axles are about 1½ ins. diameter, and the wheels ordinarily 20 to 24 ins. diameter. The weight is from 475 to 575 lbs. The car is generally driven by a lever or walking beam pivoted at the middle and having a cross handle at each end, so that four men can work it, the spur-wheel being worked by a crank with a connecting rod from an arm on the walking beam. The spur-wheel gears with a pinion on the axle, the gearing being usually about 3½ to 1. These cars will carry ten or twelve men, with tools, etc. They are sometimes operated by a sail, which method is particularly applicable for western roads with long tan-

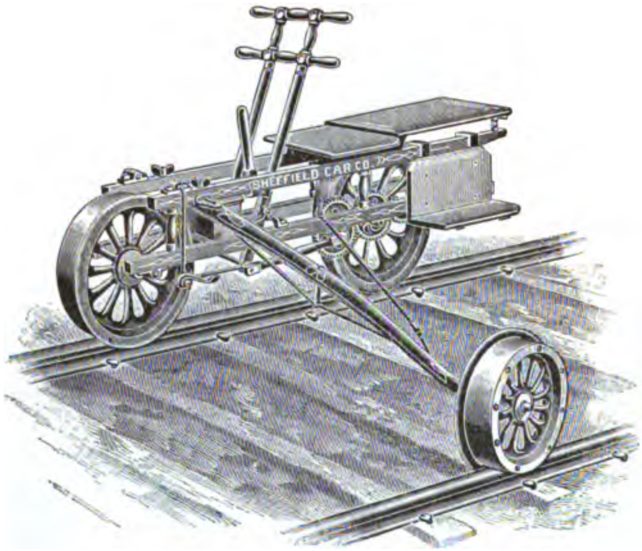


Fig. 189.—Track Velocipede.

gents, as steady winds usually prevail. In Fig. 188 is shown the standard make of the Kalamazoo hand car. This car has 20-in. steel plate wheels on 1½-in. steel axles, with a 4-in. bearing roller secured to the underside of each sill. The gears are 2¾, 3⅓ and 4 to 1; the first is used where much power is required on account of steep grades, and the last where high speed is desired on level roads, while the second is generally employed for ordinary work. The frame is of oak with four longitudinal sills 2½ × 1⅝ ins.: six cross-sills, 2 × 1½ ins.; two 7-16-in. longitudinal truss rods and two ⅜-in. transverse truss rods at each end. The platform is 6 ft. 4 ins. × 4 ft. 4 ins. These cars are made by the Kalamazoo Railway Velocipede & Car Co., of Three Rivers, Mich., and their weight is about 550 lbs. A weed-cutting hand car is described under "Clearing Right of Way," in Part II. Hand cars should be examined and lightly oiled once a week. When not in use they should be taken carefully off

the track and placed clear of trains. It is best not to leave them near road crossings, and if left there or at any place distant from the gang the wheels should be secured by a chain and padlock. The Arcus hand car hoist consists essentially of a vertical post in the middle of the car which can be lowered by a lever so as to bear on the ground and raise the wheels from the rails, thus taking the weight of the car and enabling one man to turn it round and take it off the track. Mr. Parsons, in his work on "Track," describes a light transfer table sometimes used for taking a hand car off the track easily.

Track velocipedes are light three-wheel or four-wheel hand cars in which the operator sits over one rail or over the middle of the track and propels the car by a hand lever, treadle or both. In three-wheel cars the third wheel is carried at the end of an arm which is hinged, so that it can be folded back against the other wheels for convenience of shipment in a baggage car. The Sheffield velocipede is shown in Fig. 189. This car is made by the Sheffield Car Co., of Three Rivers, Mich., and weighs about 140 lbs. Such cars weigh about 120 to 250 lbs., and are used by roadmasters, inspectors, foremen, etc., and on some roads by a man who rides over the track daily instead of trackwalking. The car may be fitted with an odometer for measuring distances. Some

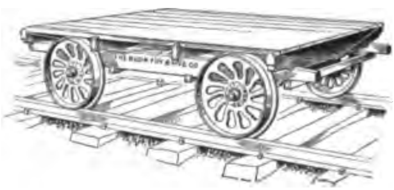


Fig. 190.—Push Car.

cars of this kind have been equipped with sails and worked satisfactorily, but care is required in handling them. Hand cars fitted with seats are used for inspection purposes, and some of these cars are operated by small steam engines, while velocipedes operated by gasoline engines have been built by the Sheffield Car Co. Some recent makes of inspection cars are built with frames of bicycle tubing, and are driven in the same way as a bicycle.

Push Car and Rail Car.—The push car is a platform car not fitted with propelling gear, and is used for carrying rails, ties, gravel, earth, supplies, tools, etc. The Buda car, Fig. 190, with a platform 7 ft. long, and 5 ft. 6 ins. wide, with four 20-in. wheels, will weigh 450 to 500 lbs. It is made by the Buda Foundry & Manufacturing Co., of Harvey, Ill. A rail car or tracklaying car, Fig. 194, has no platform, but two side sills (about 6×6 ins., or 8×4 ins.) to which the journal boxes are attached, and three or four cross timbers, 6×4 ins. or 8×4 ins., faced with iron. At each end are two rollers to facilitate unloading rails. A rail car 8×6 ft., with sills 4×8 ins., wheels 16 to 20 ins. diameter, 2¾-in. axles, and a carrying capacity of 10 to 12 tons, will weigh about 1,000 to 1,350 lbs. A plank bottom may be nailed to the underside of the middle sills to form a box for tools or supplies.

Wheelbarrows.—These may be of wood or iron, the former being more readily repaired on the section, and they should be strongly and sub-

stantially built. They need little attention beyond occasional oiling of the axle. In ditching work, a wheelbarrow with a grooved wheel to run on the rail is sometimes used.

Flags.—The ordinary flag is not reliable as a signal when the staff is stuck in the ground, as, if the weather is calm it hangs limp, while a breeze or wind may blow it parallel with the track or wrap it round the staff. This may be partly remedied by having it hung from a horizontal arm, or the staff may be fastened horizontally to a post 4 ft. high, 8 ft. from the rail. In the Tallman device the flag is wound on a roller in a cylindrical case, having a slot for the flag to pass through. This case is hinged at one end to the staff and when not in use folds against it (with the flag inside), while when in use the case is horizontal and the flag displayed. Some roads require a flagman to hold the flag always in his hand, but where a flagman is not stationed, a flag with two staves, or with some means of keeping it displayed, should be used. Iron track flags have been used. In some cases a special color of flag (blue or yellow) is used to protect track work, the red being kept for a danger signal. Flags should be kept as clean as possible, and should not be kept in use when so torn or dirty as to be unreliable as signals. When not in use they should be rolled up and tied with string. Some roads require that when track work is being done which obstructs the track, a man must be sent out in both directions (on double as well as single track), and must set two torpedoes at a distance of 24 telegraph poles and remain there, holding his flag in his hand. In foggy weather the distance should be 24 poles to the flag and 32 poles to the torpedoes. When sectionmen are working between a steel gang or extra gang and the flag of the latter, a flag should be placed in the middle of the track, about 100 ft. beyond the section gang, between it and the other gang, to warn enginemen that there is a second gang at work.

Lamps.—The ordinary lamps are of use as signals, but not of much use for work on the track, giving too poor a light. They should be kept well trimmed and filled, and placed on a shelf out of the way so as not to be broken in handling the tools. A few spare globes should be kept on hand. The oil cans should be set in a wooden box or tray filled with sand, and some oil should be kept on hand when the cans are sent to be refilled. Signal oil for switch lamps, which has become thick may be thinned with kerosene.

PART II.—TRACK WORK.

CHAPTER 14.—ORGANIZATION OF THE MAINTENANCE OF WAY DEPARTMENT.

There are two general systems of organization of the track work, or maintenance of way department. In the first, it is under the operating department, and in the second it is under the engineering department, the latter being certainly the more correct. Whatever officer is the highest authority in charge of the track department, the best system of organization is to put the entire work of every division (maintenance of way, motive power and transportation) under the direct charge of the division superintendent. He then reports to the chief engineer, the superintendent of motive power and the general superintendent, while those officers transmit all instructions to him, which he in turn refers to the proper subordinate officers under him. In this way all authority and responsibility for the work of the division are centered with the superintendent, which arrangement conduces to the economy and efficiency of the service. In most cases the chief engineer or the general superintendent is in direct charge of the track work, but on many large roads there is an engineer of maintenance of way or a general roadmaster, who ordinarily acts in the place of the higher officer for all regular work. It is well, however, to have as little subdivision of authority as possible, but the extent of such subdivision will of course depend largely upon the mileage and traffic of the road. On a large railway system it would be practically impossible for the chief engineer to attend personally to track work details as well as to all the other work of his department, and he must therefore deputize some officer to act in his place for all affairs of routine. On a smaller road, however, the chief engineer may be in direct touch with the roadmasters. The systems of organization in force on some of the leading railways are given below:

Atchison, Topeka & Santa Fe Ry.—Track work is under the general superintendent. The engineering force is composed of a chief engineer, an office engineer, a bridge engineer, three resident engineers and a supervisor of buildings. Roadmasters' divisions vary from 66 to 125 miles in length. Sections are about 6 miles long, and the number of men on each section varies according to the location of the section and the season of the year.

Boston & Albany Ry.—Track work is under the engineering department. Roadmasters have 50 miles of double track, with not less than 20 miles of branch on single track, one division having 100 miles of single track. Sections are 7 miles long on single track and 4 miles on double track, while the section gangs have 4 men in winter and 10 in summer.

Chicago, Burlington & Quincy Ry.—Track work is under the operating department. Roadmasters have 80 to 120 miles of double track, with 60 to 80 miles of branch in addition.

Erie Ry.—The engineer of maintenance of way has charge of all matters pertaining to maintenance work, including track, bridges, buildings, water stations, etc. All the division superintendents report to him on these matters, and he reports directly to the general superintendent. Plans for all new buildings, bridges and other important structures are prepared by the chief engineer, who either assumes direct charge of the construction or refers it to the engineer of maintenance of way, and thus through to the division officers through the division superintendent, to whom all other division officers report. On each division the roadmaster has charge of the maintenance of way, and has under him a master carpenter, a track supervisor and a small engineering force, which corps is in charge of an assistant engineer.

Illinois Central Ry.—The roadmasters report to the division superintendents, who in turn report to the two assistant general superintendents (one south and one north of the Ohio River). These report to the chief engineer upon all matters relating to the physical condition of the property, and to the general superintendent upon matters relating to transportation. The latter officers report to the second vice-president. A civil engineer is connected with each roadmaster's office, either the roadmaster or his chief clerk being an engineer, and the roadmasters are assisted by supervisors, who have charge of about 100 miles of track. There are 13 divisions, the shortest (near Chicago, 63 miles), and the longest (along the Mississippi River), 518 miles. The number of men in the section gangs varies in proportion to the importance of the line. On main line, with single track and gravel ballast, an ordinary section gang consists of a foreman and 6 men to a section 6 miles long, one of these men usually acting as trackwalker. This force is reduced on the less important main lines with gravel ballast to a foreman and 4 men, additional men being employed as needed to put in extra ballast, lay new rails and do other important work which cannot be taken care of by the regular gang. With earth ballast (which is used only on unimportant branch lines) an ordinary gang consists of a foreman and 3 or 4 men, but such a gang is increased when it is necessary to do any extensive ditching, general surfacing, etc. There are several hundred miles of track with stone ballast, and for this the section gangs are composed of a foreman and 6 men to a section 6 miles long, additional gangs being employed for extra work in ballasting, laying rails, etc.

Lake Shore & Michigan Southern Ry.—Track work is under the engineering department, and the roadmasters' divisions are about 100 miles long.

New York Central Ry.—The track work is under the engineering department, in accordance with the following section of the company's by-laws: "The chief engineer, under the direction and supervision of the third vice-president, shall have the care and charge of the roadbed and tracks, and all buildings and structures appertaining thereto; docks, piers, bulkheads, sheds and warehouses. Ordinary maintenance of the roadbed, track and structures shall be under the charge of the general roadmaster, in accordance with standard rules, regulations and plans prepared by the chief engineer, under his supervision and control." The third vice-president is the executive head of the operating department. Roadmasters' divisions are from 40 to 50 miles long for double track and 25 to 35 miles for four track. The standard length of section is 4 miles on double track and 3

miles on four track. The standard gang consists of 3 or 4 men on double track and 6 men on four track sections: these being in addition to the foreman in each case.

New York, New Haven & Hartford Ry.—Track work is under the operating department, and the roadmasters report to the division superintendents. The length of sections on the New York division (four tracks, stone ballast) is 2½ miles, and the section force consists of a foreman and 9 men. One man is detailed to walk the track every morning and evening.

Northern Pacific Ry.—Track work is under the operating department. The roadmasters' divisions are 100 to 150 miles long, and the sections 6 to 10 miles long. The number of men varies with the season of the year and the amount of traffic, but the average is 3 men, with a foreman.

Pennsylvania Ry.—The general manager is aided by three "cabinet officers;" the engineer of maintenance of way, the general superintendent of transportation and the general superintendent of motive power. The engineer of maintenance of way is represented on each of the grand divisions by a principal assistant engineer, who in turn is represented on each of the operating divisions by an assistant engineer. Each superintendent's division is divided into supervisors' sections, varying in length on the different divisions. The supervisor, who corresponds to what is generally known as a roadmaster, has one assistant. Subordinate to these two officers are the track foremen, whose sections are 2½ miles long on double and four-track lines.

Philadelphia & Reading Ry.—Track work is under the operating department. The section men report to the supervisors and the supervisors to the division engineers, who in turn report to the general superintendent. Supervisors' divisions are from 40 to 70 miles long, and the sections average 4 miles on double track and 6 to 8 miles on single track.

Southern Pacific Ry.—The engineer of maintenance of way acts as assistant to the general manager, and his duties embrace also those which on many roads are attached to the office of chief engineer. He has immediate supervision of all matters pertaining to the maintenance or renewal of the roadbed, track, bridges and buildings, and also has direction of all construction work. He prepares the pay-rolls and keeps the accounts of the department, the accounts being rendered to the auditor at the close of each month. He has under him a superintendent of bridges and buildings, an assistant engineer, and division engineers, who assist the division superintendents in all matters pertaining to the maintenance of the track. The roadmasters report to the division engineers.

Wabash Ry.—Track and bridge work are under the operating department. There are 13 division roadmasters, whose divisions range from 83 to 228 miles in length, all single track. The sections average 6 miles, with an average of 6½ men in the summer and 3 in the winter. During the working season the force is about 1 man per mile (single track), and this is reduced to 1 man per 2 miles when conditions permit.

Whatever the system of organization of the department, the track itself is divided into sections, the work on each of which is in charge of a section foreman and section gang. The length of sections varies according to the number of tracks, number of yards and switches, and the amount of traffic. The average length is about 5 to 7 miles on single track, and 3 to 5 miles on double track, 3½ to 4 miles of double track being equiv-

alent to 5 miles of single track. On four-track lines the length of sections is from 2 to 3 miles. The amount of work does not increase directly in proportion to the number of tracks, as ditching, clearing right of way, cutting grass, etc., average about the same in any case, the greater amount of clearing on a single track right of way compensating for the greater care usually required on double track. On double track, however, the men know in which direction to look for trains, and can therefore do their work and run their hand-car to better advantage and with greater safety. The number of frogs and switches, however, has a material influence on the amount of work, and the number of men allotted to the sections, as noted later. In Table No. 16 is shown the distribution of labor on some leading railways:

TABLE NO. 16.—ORGANIZATION FOR TRACK WORK.

Railway.	Length of roadmasters' division, miles.	Length of track sections, miles.	No. of tracks.	No. of men in section gang. Summer.	No. of men in section gang. Wint'r
Atch., Top. & Santa Fe	66 to 125	6	1	..	..
Boston & Albany	50 of d. track with at least 20 of s. track branches.	7	1	10	4
		4	2		
Chicago & Northwestern	....	6	1	..	..
	....	3½	2	3 men.	..
Chicago, Burl. & Quincy	80 to 120 on main line, plus 60 to 80 of branches.	2½ to 5	1	4 to 7	2 to 4
		5 to 6	2		
Chicago, Mil. & St. Paul	100 main line	4 to 5½	1	3 to 7	2
	100 main line.	3 to 3½	2		
Illinois Central	100	6	1	½ to 1.1 per mile.	..
	....	4	2		
	....	8	brchs		
Lake Shore & Mich. Southern	100	5	1	10	4
	....	3½ to 4½	2	..	..
Michigan Central	....	5	1	4	3
	....	4	2	..	..
New York Central	40 to 50	4	2	3 to 4	..
	25 to 35	3	4	6	..
N. Y., N. H. & H.	36 to 148	4 to 7	1	..	..
	....	3 to 4	2	8	4
	....	2	4	9	..
Northern Pacific	100 to 150	6 to 10	1	Average 3.	..
Pennsylvania	....	2½	2 to 4	5 to 9	..
Wabash	83 to 261	6	1	6½	3

Roadmasters.

The position and responsibility of the roadmaster vary on different roads. In some cases he is at the head of his department, and in others he occupies a more subordinate position. He is the direct head of the track work on his road or his division, being the intermediary between the executive officers and the working force. He should therefore carefully cultivate a spirit of good feeling between himself and his men, and let them feel that he is friendly and just to their interests and just in his dealings with them.

It is being more and more generally recognized that engineering knowledge and experience are required in track maintenance work, and that a roadmaster on an important road should be something more than a high grade of section foreman. As to the question whether or not the roadmaster should be a trained engineer or what is vaguely called a "practical man." promoted from the ranks of the section foreman, a little consideration will make it very evident that the former is the best fitted for the duties and responsibilities of the position. He must, however, be not only familiar with railway work in general, but must also be thoroughly familiar with the practical details of track work, for otherwise his subordinates and

the laborers will have little respect for him. The "practical man" is apt to have a contempt for instrument work (based on his ignorance of such work), and to rely upon getting his switches in and making his curves easy riding by means of his eye and "trial and error." He is also liable to be inefficient in the handling of men. It has been pointed out by Mr. B. Reece, in a paper on "Railway Track Repairs" (Transactions, American Society of Civil Engineers, 1884), that the practical man is apt to rely more upon special rules and instructions, and upon personal direction, than upon general rules and written orders; although this latter plan is the better in directing large bodies of men, leaving the former to the subordinate officers. Besides this, the education of the section foreman is often too limited to fit him for higher responsibility, while being unfamiliar with general principles he is likely to be won over to the approval of any track device, etc., submitted to him by an enthusiastic inventor or a glib-tongued salesman. His lack of knowledge of operating conditions and of railway economics also makes it hard for him to understand how and when it is best to expend labor and money. Neither is the foreman, as a rule, likely to be familiar with instrument work, while a roadmaster (if in responsible charge) should be able to take levels, set out curves, and do other work of this kind without calling upon the engineering department.

In regard to the details of the work of the roadmaster, he is responsible for keeping the track, roadbed, bridges, culverts, telegraph line and everything pertaining to the roadway, in repair and in proper condition for safe use. The rules and regulations which govern him differ on all roads, in accordance with local conditions and organization, but the following general outline of his duties, which is compiled from the rules contained in the instruction books of a number of railways, will give a very good idea of the scope of his work and responsibilities. Where there are division roadmasters, or supervisors, their duties and responsibilities are practically the same, but on a smaller scale. Of course much of the work noted below has to be attended to by the foreman, but it is all included in the roadmaster's responsibility.

The roadmaster (under ordinary systems of organization) is held responsible to the official directly superior to him for the maintenance and condition of the track on the division, for the safe keeping and proper use of all track material and tools, for the condition of the tool houses, section boarding houses, tanks, pumping stations, etc., and for the proper supply of water for trains. He is also responsible for the condition of yards, culverts, trestles, bridges, grade crossings, cabins, platforms, turntables, fences, cattle stations and all minor structures. He must spend much of his time on the road, but must not neglect proper attention to office duties, such as the checking up of time-books, pay-rolls and records, the preparation of requisitions and reports, and the answering of letters from other departments. He is usually allowed a clerk to see to the correspondence and general office work. He must be frequently and systematically out on the track, not merely looking at it from the engine or the rear platform of a train, but walking over the sections, personally interviewing the foremen, and carefully inspecting all new work. He is usually required to pass over a part of his division every day, except when engaged in checking up time-books at the end of the month, and to pass over the whole of the division on foot or

on a hand-car at slow speed at least once or twice a month, or oftener on mountainous or dangerous divisions. He must record the dates on which he goes over the division, noting whether the trip was made on foot, by hand-car or by train; and must record all important work and its progress. He should be thoroughly posted as to the physical condition of the road and the daily disposition of his forces.

During his trips he must look closely into details of work, and talk frequently with the foremen, calling their attention to defects or bad practice, give them instruction and advice (but not "nagging" them), and being prompt to award either praise or blame. He should see that his orders are thoroughly understood and properly executed, particularly on special or important work; and should enquire of the foremen as to their plans for doing coming work. He should never issue orders directly to the men under his subordinates, as that tends to injure proper discipline and the respect for the foreman's authority, and he must remember that the foreman (and not the roadmaster) is in charge of the gang.

He must see that the foremen are properly supplied with time-books, time-tables, blank reports, etc., and that they properly use and return them; and also that they make proper reports of accidents, cattle killed, fences burned, etc. He must frequently and closely inspect the track to see if it is kept in proper condition as to line and surface, accurate gage, alinement at tangent points, superelevation on curves and widening of gage at curves. Frogs and switches must also be carefully examined as to condition and position. The accuracy of the foremen's gages and levels must also be occasionally tested. He must see that the proper expansion shims are used in laying new rails, and that new ties and ballast are properly used. Also that all frogs, switches and fixed signals are placed in accordance with standard plans. The car and tool equipment, lamps, etc., must be inspected, to see that they are in efficient condition and properly used, and that all supplies are accounted for when new ones are requisitioned for. Engineers' curve and distance stakes must be looked to, to see that they are not disturbed, and when they need renewing he must either set them out or report to the engineer. He must see that track signs, bridge tell-tales, mail cranes, etc., are in good and proper condition, and that all printed notices at farm crossings, etc., are properly posted. Fences, gates and gate fastenings must be looked to, and reports made of cases where farm gates are habitually left open.

The roadmaster has authority over the pumping station men, and must see that they keep the machinery clean and in order, and that the fuel is neatly stored and cared for. On the failure of water supply at any station, telegraphic notice, followed by a written report, must be sent to the superintendent. In winter he may also order the foreman to detail men to look after the stoves to prevent freezing up of the water stations. He must see that all buildings and their surroundings are tidy and in good repair, that section boarding houses are kept neat and clean and that proper food and accommodation are provided for the men. If this is not done it will not be easy to keep good men on the road, and track work will be expensive in consequence of being always in the hands of new men. He must also see that telegraph linemen, fence gangs and bridge gangs are afforded proper facilities and assistance in making repairs. Whenever any structure is being built or work is being

done on the company's property by other than employees of the company, the facts must be reported, unless it is positively known that proper authority has been obtained. The roadmaster must exercise a general oversight of all work performed on the division by contractors, bridge carpenters, telegraph gangs, etc., in case anything should interfere with the safety of the track. A special inspection of all waterways should be made before the winter or rainy season, any necessary repairs being then made to trestle bents or banks of streams, and all obstructions removed.

Arrangements must be made for the proper execution of all new work ordered, and the roadmaster will obey instructions issued in regard to such work, including ballasting, re-laying rails, putting in switch or interlocking work, laying additional tracks, rearranging yards, reconstructing bridges, etc., and the execution of the work should receive close attention. The roadmaster has full charge of all construction trains on his division, and must lay out the work for them. He must also see that comfortable quarters and wholesome and sufficient food are provided. All orders for work done by construction and material trains are given by him, except in cases of emergency. Insufficient motive power on work trains must be at once reported, as construction trains are very expensive and require the best motive power to insure their economical operation.

The roadmaster should annually inspect all the ties which the section foremen mark as needing renewal, and from this personal examination prepare a requisition for ties needed in the coming year, checking the foremen's counts and requisitions. This estimate must be sent in to the proper officer by a specified date each year. No ties must be removed without his approval, and those removed should not be disposed of until he has seen them. He must carefully examine the requisitions made by the foremen, and ascertain if the articles are really needed and in the quantities asked. Requisitions must be made in writing and sent by mail, the telegraph being used only in emergencies or when delay would result in loss to the company. He must personally receive all materials contracted for, such as ties, ballast, wood, etc., and must strictly enforce the printed specifications for the same, and arrange for handling and unloading or storing. Ties must be properly piled so as to facilitate inspection and marking with a hammer or brush. Wood ricks must not be more than 60 ft. long, and 6 ft. high, with 5 ft. between ricks to admit of proper inspection. Each rick must be thoroughly marked with whitewash or lampblack so that any misappropriation of wood can be checked. No material must be piled within 8 ft. of the rails. He must also supervise the storing and shipping of scrap, and its disposal at the scrap yard or pile. He must not permit old material to be sold or given away or otherwise disposed of by the men, and must see that foremen do not allow laborers to remain at the section boarding houses to chop wood or do odd jobs for the boarding master.

The roadmaster is expected to investigate and keep himself posted as to the wear of track material, rails, splice bars or special joints, ties, etc., reporting results from time to time, especially in regard to material under experimental trial. He should mark on his rail profile all the new rails laid from time to time, giving the date, brand, and exact location with reference to the nearest mile post; this being in addition to the monthly written reports of rails laid. This enables the chief engineer to keep a correct account of the wear and life with reference to tonnage. All cases

of broken rails should be carefully investigated in detail, and full reports made. Whenever a broken rail is found in the main track, a report should be made by the roadmaster after careful investigation, and about a foot of the rail on each side of the break should be cut off, labeled and stored away.

The roadmaster is authorized to discharge any supervisor or division roadmaster, section foreman, road watchman, conductor of construction train, or other subordinate, for neglect of duty; he suspends him and makes report to his superior officer in case of accident resulting from such neglect. Changes of foremen should always be made at the beginning of the month, except in case of emergencies. In reporting the discharge of a foreman the cause should be stated, so that a record of the man's standing can be kept for future reference. A record of all foremen (and sometimes trackwalkers also) employed, discharged, resigned, transferred, promoted, married, deceased or sent to hospital, must be sent in monthly. When a foreman leaves the service the roadmaster must see that all tools and other company property are properly accounted for and must examine his time books to see that all accounts are correct. New foremen must be carefully instructed in their duties, and must be closely questioned to ascertain if they correctly understand them.

The roadmaster must see that section foremen, foremen of extra gangs and conductors of work trains are supplied on the first day of each month with the necessary blanks, such as check rolls, time-books, diaries, reports of work and materials, board bills, etc., and that the use of these blanks is explained to all new foremen. During his trips he should examine these blanks to see that they are being properly filled in. These returns should be handed to him or sent to his office by the first train on the night of the last day of the month. On receiving these returns he should examine them carefully, making the mark "Voucher" opposite the names of all men on the check rolls to whom he has issued time vouchers. The several reports, check rolls, diaries, board bills and time checks, together with the roadmaster's journal, must then be sent to the proper officer.

While passing over his division he should always carry a book of blank time vouchers, so as to be able to issue a voucher to any trackman who presents a properly filled time check. In issuing the voucher he should in all cases require the man to write his name in the blank space provided for that purpose, so that the voucher may be used as far as practicable to identify the holder. Receipts on standard forms or blanks must be taken for every issue of time cards and for instruction books. These receipts are to be pasted in alphabetical order in a book for preservation and reference.

The roadmaster is required to keep a journal or diary, in which he must enter the location and the dates of beginning and ending of all work under his charge, such as grading and laying sidings, changes of line, laying new rails or ties, ballasting, experimental ties or joints, etc. He has also a pocket notebook, in which he records how each trip is made (whether on passenger or freight train, on handcar or on foot), and also any points of interest for record or of use in making up his returns, such as material delivered or required, the number of men employed, etc. As a check on the time of the section men he should note here the number of men in each gang as he passes. These books should be of a uniform standard size, supplied by the company, and sent to the superior officer each month. Memorandum books and all blanks are obtained from the superior officer regularly or by

requisition. He should have his watch inspected once every three months and should compare it with standard clocks and with the watches of the foremen as often as possible, seeing to it that the foremen take his time as correct. To the roadmaster should be made all applications for detailing men from the section gangs to assist fence gangs, telegraph repair gangs, or bridge gangs, or to clear stations grounds and yards. No authority should be given to foremen of such gangs or to station agents to employ section men for any work without the permission of the roadmaster.

The roadmaster is responsible for the proper handling of gravel and construction trains, and all orders for running them must be made by him. He must be familiar with the train rules, special orders, etc., and keep himself at all times in communication with the transportation department. Disregard of signals by trainmen must be promptly and invariably reported. He must see that the track and roadway are in proper condition for the winter. In times of storm he must keep the superintendent fully advised of the condition of the road, and he must see to the proper distribution and work of trackmen to help the snow gangs on their sections.

The roadmaster must closely investigate every accident that occurs on his division, and make a full written report in the proper form, giving the cause of the accident and all information possible. He must be ready at all times, both day and night, to render any assistance that may be called for in case of accident or detention to trains. On receiving notice of a wreck he must proceed to it at once, take charge of the track forces not required in removing the wreck, and put the track in condition for the passage of trains, or build a temporary track around the wreck, all with the least possible delay. Such material as broken rails, axles, etc., which may be of use in determining the cause of the accident, must be preserved. When cars are broken up or burned for removal at a wreck, he should note the style of car, and the number and initials of each car thus destroyed.

Section Foremen.

The section foreman is the most important of the men in the working force, and should be a man of good judgment and firm character, so that he can rule his men and get on comfortably with them. He should be able to read and write and keep simple accounts, so as to keep the necessary records of labor, supplies, etc. For this clerical work he should have a desk and office in the section tool house. He is usually required to walk over his section every other day, or at least once a week, this depending, of course, upon the length of the section, the condition of the track and the amount of traffic. He has also to make a monthly inspection of and report upon all culverts, trestles, bridges, tunnels, etc., on the section, and must also inspect any such structures at times when they are liable to be damaged by floods or otherwise. He should be subject only to the orders of the roadmaster. Train dispatchers, station agents, claim agents, bridge foremen, tie inspectors, etc., should not be allowed to give orders direct to the section foreman, or to call upon him to supply men for any purpose, except in case of emergency. Where two or more gangs work together on emergency work, as in case of accident, the senior section foreman is in charge, subject to the direction of, or until the arrival of, the wrecking foreman, roadmaster, engineer or superintendent, as the case may be.

As to section foremen working with their men, it may be said that with

small gangs, up to, perhaps, five men, the foreman can very well join in the work and still keep a general oversight of it. With a large gang of eight men or more, or with extensive work in progress, he will, as a rule, have all he can do to see that the work is being done properly, especially when there are new men to be broken in. A foreman, however, who works regularly as one of the gang is not likely to have their respect or to get the best work out of them. This, of course, depends partly upon the character of the work. Putting in switches or lining up track will require much watching, while in cutting grass, or in general trimming up, the foreman can well work with the men, even if he has a large gang, but at the same time keeping an eye on the progress of the work as a whole. It is his duty to direct the operations, and to see that they are carried out properly, and to supervise the track work generally, being careful to have the work done systematically and not at scattered points on the section.

Where large gangs are worked it is a good plan to permit the foreman to appoint an assistant foreman, who, ordinarily, works with the gang, but takes charge in the absence of the foreman. In promotions to the rank of foreman, the assistant foreman should be given the first choice. The foreman should have power to appoint and dismiss his assistant, making the necessary report of the circumstances, and being, of course, responsible for his ability and for all the work done by him, the roadmaster having nothing to do personally with any trackman below the grade of foreman. The assistant foreman should be selected not only for his technical or practical skill, but also for his executive ability in directing the work and handling the men. He may be given a slight increase in pay over that of the regular laborers.

The foreman employs and discharges the men of his gang, and also the bridge and other watchmen on his section, and keeps proper records of all the men and their work. He must treat his men properly, without fear or favor, and without the use of profane or abusive language, endeavoring to promote harmony and good feeling among them, and checking any tendency to idle or loaf. When the men do not live at a section house, he should know their addresses, and arrange a system by which one man can call others in case of accident or emergency at night. He should have authority to employ extra men temporarily during heavy snow, and should have a few extra men assigned him when any extensive switch work, etc., has to be done.

He has charge of all repairs on his section, and is responsible for the proper inspection and safety of the track, bridges and culverts. He must see that ditches are clear, and that drainage is not obstructed, that weeds and grass are kept cut along the right-of-way and around trestles; also that ties are tamped, rails properly spiked and jointed; and track in line and surface and in good condition generally. He attends to the fences and telegraph lines, resetting poles when necessary; and also sees that water stations are in order and water barrels at trestles, etc., kept filled. He must also see that the gang has the proper equipment of tools and supplies, and that this equipment is kept in good condition, properly used, and properly arranged in the section house. He must have a reliable watch, and must daily, if possible, compare it with and regulate it by the clock in the telegraph office at a station or signal tower on his section, so as to keep standard time, and so be prepared for regular trains. He must be

familiar with train rules and schedules, and look out for signals on and messages from passing trains.

The foreman is supplied with time-books, pay rolls and diaries, and carries them with him, ready for inspection by the roadmaster at any time. All entries must be written up in the time-book, etc., every night for the day just closed, and then all footed or totaled up together at the end of the month. The books, board bills, etc., must be properly entered up and certified, and must be sent to the roadmaster by a night train on the last day of the month, or by the first available train on the first day of the new month. On some roads he is furnished with duplicates of these reports, so that he can retain copies of the returns made to the roadmaster. On the check rolls or time-book he enters daily the time worked by each man, and on the diary he records the total time made by the gang. Entries of materials used in construction or repairs must be made daily and footed up at the end of the month. He also makes reports of material used and on hand, of work done, fences or other property burned, cattle killed by trains, and makes requisitions on the roadmaster for material required. The time-book entries must show not only a correct report of the time worked by each man, but also the kind of work upon which he was engaged each day. The character of the weather should also be noted.

Should a man leave or be discharged before the end of the month, the foreman gives him a time-check (showing the amount of time he has worked) which he can present to the roadmaster, who will take it up and issue in its place a time-voucher, which is payable by any agent of the company having funds for this purpose. The foreman must require the man to sign his name on the back of the time-check if he can write, and the man can, if he wishes, retain this check, which can be used to identify him to the roadmaster or in the pay office. To secure payment to the section-house keeper and others furnishing board and lodging to track and bridge men, the foreman supplies such persons on the first of the month with blanks for "board due," which they are required to properly fill out and have signed by the men from whom the amounts are due. These blanks are returned to the foreman on the last day of the month, and from them he enters the amount due by each man in the "board" column of the check-roll, opposite the man's name. Different railways have different styles of time-books, blanks, etc., and particulars of these will be found in the chapter on "Records."

Trackwalkers and Watchmen.

In addition to the regular work on the track, the section must be inspected at least once a day (except Sunday) by a trackwalker. On most important lines this man is in addition to the regular section gang, and he usually starts out in the morning in the opposite direction to that taken by the gang, while on roads having much night traffic he must also go over the section in the evening. The time of starting out can usually be arranged so that the man can go over the section shortly before the principal trains, and can, perhaps, return by train. In the afternoon he may work for a few hours with the gang, and then go over the section again, returning by train. On double track, he may make a round trip over each track (one by day and one by night), and on four track lines he passes once over each track. In summer, and in fine settled weather, the trackwalker can join the gang in the afternoon, but in stormy weather, or when

there is liability of such dangers as washouts, the blowing of trees or telegraph poles upon the track, etc., he should spend all his time patrolling the section. After a very heavy storm the trackwalker and one of the laborers should go over the section and look out for any damage requiring immediate attention.

On the Erie Ry. the trackwalker works under the direction of the foreman. In summer he makes one trip daily over that part of the section which is not covered by the foreman on his way to and from work. In winter or in stormy weather he covers the section twice daily. When tie renewals are being pushed he works with the gang for the remainder of the day, and in the spring and autumn he spends the remainder of the day in tightening bolts and replacing broken spikes. At all times he gives immediate attention to any necessary light repairs of frogs, switches, etc. On the Illinois Central Ry. one of the section men acts as trackwalker, except that on some portions of the line where traffic is unusually heavy an extra man is employed as trackwalker. The Chicago, Milwaukee & St. Paul Ry., and some other railways, only employ trackwalkers at certain seasons of the year when it is made necessary by reason of heavy rains or something of that kind. Other roads do not employ regular trackwalkers, but send a man over each section on a velocipede, leaving all repair work, etc., to the section gang. The foreman is sometimes required to act as trackwalker, but this interferes with his charge of the gang, except that on roads with light traffic he can go over the section after he has first started the gang at work. On branches or lines with light traffic, one of the laborers may act as trackwalker, making one trip and then returning to work with the gang. Where there are many switches or signals to be attended to, the lamp man may act as trackwalker, making two round trips over the section; the first in the morning to extinguish the lamps; the second in the afternoon to fill, trim and light the lamps. In such case the foreman or a laborer should make an extra trip in bad weather.

The trackwalker is ordinarily equipped with a track wrench, a light hammer (having one end pointed), 2 red flags, 4 torpedoes, and a few bolts, nuts and spikes in a bag, while sometimes he also carries a tamping pick. On sections with dangerous rock cuts he may also have a few sticks of giant powder or other convenient and safe explosive to shatter rocks that may have fallen upon the track. It is sometimes recommended that he should also carry a pair of short pieces of plain splice bars, with one hole in each, so that he can bolt these to any broken rail, putting the bolt through the open space of the fracture.

In walking over the track he looks out for broken rails and burnt ties, raises low joints, picks up loose material and places it at the side of the track, tightens loose bolts and spikes or puts in new ones, examines frogs, switches and switchstands, and in warm weather throws stub switches to see that they work freely, reporting them if stiff. He must see that cars on sidetracks are clear of the fouling points. He also has to look out for broken or defective signals, to look out for and repair fences, close farm gates (reporting any that are habitually left open), look out carefully for fire on bridges and trestles, and see that the water barrels on wooden structures are kept full; he must also see that culverts are clear and cattle-guards safe, drive stray cattle off the right of way, and in general "do anything and everything to protect the railway from accident." After a

heavy storm he must be specially observant, and look out for evidences of washouts or of slides of banks or cuts. In winter he must also clear snow where it is packed about frogs, switches, guard rails and the flangeways of crossings. The night trackwalker is only expected to walk the section and see that the track, etc., is safe; he is usually provided with a lantern and torpedoes. When the trackwalker finds any place unsafe for the passage of trains he must place a red flag in each direction (or against the traffic on a double-track line) at a distance of 90 rails or 15 telegraph poles, and place a torpedo on the rail. The torpedo should be on the rail on the engineman's side of the track, and the flag on the same side of the track, 3 ft. from the rail.

It will be seen that the trackwalker has an important and responsible position, which should only be filled by an experienced and trustworthy man. It is sometimes assumed that his work is principally to look after loose bolts, but in the main the amount of trackwalking is independent of the work done in tightening the bolts, and while some roads do not permit the trackwalker to touch the bolts unless he sees something wrong, yet no reduction in the trackwalking would be justified, even if there were no bolts to tighten. Too much care can hardly be taken in guarding the track, and in watching it in time of storms to prevent accidents as far as possible and at least to prevent accidents to trains.

Any particularly dangerous spots, such as tunnels, loose rock cuts, sliding slopes of cuts or banks, rock cuts in winter, and culverts and trestles in time of flood, should be guarded by a watchman. This man should be provided with lamps, flags and torpedoes, and, if necessary, with tools (a pick, shovel, ballast hammer, wheelbarrow, etc.), and some sticks of giant-powder to break up rocks that may fall on the track. Where watchmen are stationed permanently at such places, cabins similar to gatemen's cabins should be provided. These men must be of sufficient experience to appreciate the responsibility of the post and to be relied on in case of emergency.

With track of average condition, the trackwalking usually costs more on curves than on tangents, unless more attention is given to the maintenance work on the latter. Watching also costs more, as an engineer cannot see ahead on a curve, and in case of a storm or flood, it may be necessary to station a watchman in a cut on a curve, when it would not be necessary if the track were on a tangent.

Where the block system is in force, the trackwalker's beat may be between certain block towers, and he may be required to enter the tower and sign his name and the time in a record book, the signalman also signing the record. Watchmen at special points may also be required to report at a block tower at stated times. On some roads, including the Erie Ry., the watchmen on rocky divisions are supplemented by a special "rock gang," composed largely of quarrymen, who are experienced in climbing and in detecting loose or dangerous rocks, the removal of which is done by them. This gang is in charge of a special foreman.

Grade-crossing watchmen or gatemen have usually nothing to do with the track, but should be instructed to see that the flangeways are clear and that the crossing planks are securely fastened to the ties. Bridge watchmen must see that water barrels are kept full on wooden bridges and trestles, and must follow every train and extinguish any hot cinders

that may have fallen from the engine, and at the same time look for signs of sparks from the engine smokestack which may have lodged in the upper part of the structure. They must keep all combustible material cleared from the vicinity of the bridge, keep abutments, copings and bridge seats clean, and report any bulging or sign of cracking of the abutments or masonry. They must also watch for any evidence of undermining of piling or abutments; examine the structure and report to the section foreman any decay or defect, slackening of nuts, loose rivets, etc., and must observe the structúre during the passage of trains, noting specially if trains cross at too high a speed. Every train must be signalled by a white flag or lamp if all is safe. They should prevent all persons, other than employees, from walking over the structure. Drawbridge tenders must look after the locking and other gear and the signals or gates, reporting promptly any sign of defect in the structure or in the operating, turning or locking machinery. Bridge watchmen and drawbridge tenders may be set by the foreman to do incidental work when not engaged in their special duties.

Force and Labor.

The number of men employed upon each section depends upon the financial conditions of the company, the condition of roadbed and track, the season of the year, and the amount of traffic. This latter is one of the most important considerations. On the Illinois Central Ry., with wide extremes of track and traffic (700 train movements per day on the eight tracks of the Chicago terminal, and one local train each way per day on the Dolgeville branch), the number of men varies from 1 1-10 man per mile on busy double-track sections to ½ man per mile on branch lines where the traffic is light. The maximum gang is about 10 men and a foreman in summer on single track. The minimum is reached on some Western roads with light traffic, where the foreman and one or two laborers are required to look after 6 to 10 miles of single track for 4 to 6 months of the year, and under such circumstances the question of appearance of the track must be left out of consideration. The average, however, as shown by the table already given, is 5 to 7 men on single track in summer, and 2 to 4 men in winter. With a small gang, the section should not be too long, as in case of finding a broken rail, etc., there may not be time to flag both ways or to notify the men of the adjacent section to help make repairs.

As an average, it is estimated that 1 man per mile of single track, or 1½ men per mile of double track, with a foreman and trackwalker to each section, will be force enough to maintain the track in proper condition if the material is good. Where sidings exist it is usual to take two miles of important siding or three miles of unimportant siding as equivalent to one mile of main track. As a rule, it is not economical, though sometimes necessary for financial reasons, to reduce the force below about a man to two miles on ordinary sections, as such a reduction leads to deterioration in track, with consequent injury to the rolling stock, discomfort and danger to passengers, and eventually an inevitable heavy expenditure for repairs due to insufficient expenditure in maintenance. The number of men is increased in the spring and reduced just before winter sets in; but the number should be reduced gradually, so that work in hand can be safely and thoroughly finished and cleared up, and not hurried over. In

the winter, when the rails, ties and ballast are in good condition, and in a locality where no large force is necessary to clear snow, the number of men may be cut down to two or three, besides the foreman, keeping just enough to do watching, clearing and occasional shimming. For handling snow extra men must be engaged, and the foreman should have authority to employ such extra men on emergency.

The number of switches and frogs on the section has a considerable influence on the amount of work to be done and the number of men required, varying, of course, with the amount of traffic. The New England Roadmasters' Association in 1895 adopted a report to the effect that 15 switches and frogs on an ordinary section would necessitate the employing of an extra man in the gang. This refers to both main track and yards under conditions of moderately heavy traffic, and the number of switches and frogs requiring an extra man would be less than 15 in the case of a busy yard or terminal. Where yards occur the section must be shortened or the force increased, but with large yards it is best to have a separate gang or gangs under a yard foreman, with assistant foremen if necessary.

Many railways employ extra or "floating" gangs to do fencing, relaying rails, ballasting, general surfacing, etc., and sometimes new switch work is also entrusted to them. It is far better, however, to have all work on the section done by the regular gang, and a good foreman and gang ought to be competent to do all ordinary switch work on the section, with the occasional assistance of a few extra men when extensive work is to be done. The extra gang aims to get its work finished as quickly as possible and has not so much regard to the permanence of the work as has the gang which is in permanent charge of the section. Besides this, the frequent appearance of the floating gang spoils the discipline and the self-reliance of the regular gang, so that the men and foreman get in the habit of expecting to have any little work out of the ordinary line to be done for them, which is an idea not conducive to good work. It is, therefore, well to have as little work as possible done for the regular gangs, and then they will be more capable and self-reliant, while the foreman cannot escape the responsibility for work done or neglected by him.

About once a year the track must be surfaced, lined and gaged, have new ties put in, and low joints raised, etc. This work can best be done in the spring, so that as soon as the frost is well out of the ground the gang should be filled up to the full number that the foreman can handle, say 10 to 15 men. The work can be done to best advantage by commencing at the end of the section and working back. All heavy work can thus be done in time for the increase of traffic in the summer, and the track will then be in such condition that the force may be cut down when farm work and harvesting begin to take the extra men away. If the heavy work is thus promptly disposed of, the track can be maintained during the summer with a force of about 1 man per mile, which is the lowest economical average for ordinary work. In the autumn there is ditching and clearing to be done, and the track to be put in condition for the winter. When this is done, the force can be cut down to the winter allowance. The work of the sectionmen should be reduced to a routine, and nothing outside of their regular work required of them, without the authority of the roadmaster, through whom should come all orders to the foreman, as already noted. It is bad practice, and no economy, to allow the track to get in

bad condition in summer for want of enough men to maintain it, as a larger force than usual must then be employed in the winter or late autumn, when work cannot be done to good advantage.

There is too often a tendency to leave anything a little beyond the ordinary work to be attended to on Sunday, but this is a most reprehensible practice, spoiling the men's temper and generally resulting in a loose kind of work. Men need, and should have, a day of rest, for its physical as well as moral effect, and if they are required to work for 13 days they will not do a fair day's work during each of the last 6 days. In case of emergency or accident, etc., the men should, of course, go to work at once, but it is entirely unnecessary to put them at switch work or relaying rails on Sunday. Such men as Charles Latimer (Chief Engineer of the New York, Pennsylvania & Ohio Ry.), James Furber (General Manager of the Boston & Maine Ry.), and Col. W. H. Paine, were prominent in their advocacy of Sunday rest on railways, and Mr. Latimer stood easily at the head of American roadmasters in his day. If the roadmaster has properly instructed the foremen and laid out the work properly for them, it will be possible to get the work done on week days, except in special cases on busy suburban lines, terminals, or where the traffic is exceedingly heavy. Consequently the work should never be done on Sunday without good reason. It is an expensive practice to spend 6 days in preparing for a large amount of work to be done on Sunday, with all the section gangs that can be conveniently got together, as the work is generally done with a rush, and the best work can never be done where a number of foremen are working on some other man's section. Besides the question of economy it must be remembered that the sectionman has few opportunities of spending time with his family and friends, and to deprive him of these even on Sunday is not only unfair, but is opposed to the permanent interests of his employers. The man (whether foreman or laborer) who is best to be depended upon is the man who gets fair treatment and a fair day's pay for a fair day's work.

Another bad policy which is frequently found in track service is that of employing the lowest and cheapest grades of labor on the track. Good, permanent results are not to be expected from such a class of labor, and the employment of foreigners who cannot speak the language, but have to be communicated with by signs, is certainly not conducive to good work. Inefficient and careless men should be discharged without delay, whether foremen or laborers. The improvement in the grade of labor rests almost entirely with the railway companies, for good men are always to be had at reasonable wages. It has, however, been pointed out by the author (in a paper on "The Relations of Track to Train Service" in "Engineering News," June 15, 1893) that railway companies, including more especially the directors and the higher officers of the financial departments, very generally fail to recognize the importance of the track, and to realize the economy of proper maintenance of track and road. Not only are renewals delayed, old structures patched up and repatched, and safety equipment dispensed with, but track forces are reduced and their wages kept down. There is a strong and widespread sentiment of discontent among section men and foremen at the lack of remuneration and encouragement; and it is hard to keep a permanent gang, except on roads where a more enlightened system is in force than that of considering any tramp or laborer as

good enough for trackwork. The trackmen's work is little regarded; yet if these men relaxed their vigilance or failed in their duty, not all the skill and faithfulness of the enginemen and train crews, or the elaborate equipment of the trains, could give a satisfactory train service or prevent accidents. A little inattention to a weak spot in the track, a neglected loose joint, a defective switch or frog, an overlooked broken rail, or spikes not properly redriven, and the "lightning express" goes into the ditch with more or less disastrous results, and involving more or less expenditure for damages, repairs and compensation. Trackmen who understand their work are valuable, and the railways should endeavor to retain their services by encouragement in the line of promotion. Unskilled laborers may be employed from time to time for extra work; but it is as false economy to have a constantly changing gang of green sectionmen as it would be to follow the same practice with enginemen, trainmen or machinists. These green sectionmen will use more time and material in doing bad work than experienced men will use in doing good work. And yet, perhaps, the road which is thus foolishly saving cents in trackwork, and giving its trackmen just cause for complaint, is spending dollars on elegant palace cars, increasing train speeds and advertising its fast trains and elegant equipment, ignoring the destructive effect of such service on a weak and insufficiently maintained track.

On some Southern roads there is an "apprentice gang," in charge of a foreman, and the green men who join the service are given proper instruction in this gang, instead of having to pick up their knowledge as best they can while working with a regular gang. Men trained in this way are men worth having, and will make good foremen afterwards. It has already been noted that in large gangs it is well to allow the foreman to appoint an assistant foreman, who will work with the gang while the foreman is present and take charge of it when he is absent. A system of rewards, either as premiums for work or as an increase in pay to the better and older foremen, is employed to advantage on several railways. Further particulars of this are given in another chapter.

Men should not be employed who are under age, elderly, weak or incapacitated, or who suffer from deafness, consumption or other diseases. The foreman must not excuse habitual neglect of duty, but should promptly dismiss or suspend unfaithful employees. No man should be discharged without cause or for the purpose of making place for another, but all the men should understand that they are in line of promotion, their advancement depending upon faithful discharge of duty and capacity for increased responsibility. On most roads the use of intoxicating liquors by the employees on duty is strictly forbidden, and this rule should be most rigidly enforced, while men who habitually drink too much when off duty should be dismissed. It may not be amiss to refer here to the admirable "white button" temperance movement which was originated among railway employees of every grade of service by Mr. L. S. Coffin. It is a good plan to have a rule prohibiting the offer of testimonials or presents to superiors, or the acceptance of such by the superiors.

Work-Train Conductors.

The conductor of a work train is usually appointed by the roadmaster, subject to the approval of the division superintendent or other officer of

the transportation department. He must see that all ditching, ballast and boarding cars are in good running order, that the boarding cars are clean and neat, and that good, substantial food is furnished to the men. He must be familiar with train rules, and study the rules and instructions issued to track and bridge men, and also familiarize himself with all kinds of work pertaining to the maintenance of track. Ditches must be cut according to the direction of the section foreman. He must see that care is taken in unloading material, that new ballast is cleared to leave a proper flangeway along the rails, and that skids are used in unloading rails. In distributing new rails, he must note in a book the initial and number of each car, and the number and lengths of rails on each car.

He must notify the division roadmaster when ordered by the roadmaster to distribute material, such as ties, rails, ballast, etc., so that the division roadmaster can notify the section foreman and be with the train while working on his division. He makes a weekly report of work done, materials used, delays to work, insufficient power of engines furnished, etc. When the train is delayed and likely to be held for some time, he must put the gang at work ditching, weeding, or clearing station grounds and yards. He must understand that his desire to get the work done and his train out of the way must not lead him to do hasty or careless work.

The foreman of the work-train gang should be the conductor, sharing responsibility with the engineman, as in regular train service, for a conductor who has no other duties outside the train is apt not to work in harmony with the foreman, who is interested in and held responsible for a fair day's work. A foreman who acts as conductor gets a good knowledge of the trains, which enables him to arrange his work to the best advantage (especially in the smaller items of work, which consume so much of the time), so that it can be done within the working limits assigned. He should be an expert track foreman, and be provided with an assistant foreman, and also with a timekeeper, if he has a large gang. Further particulars are given in Chapter 22, under the heading of "Ballast and Work Trains."

Minor Track Officials.

Master Carpenters.—These usually report to and receive orders from the roadmaster. They have charge of the repairs of buildings, bridges, trestles, stations, water tanks, pumping stations, etc. When making ordinary repairs they must see that the main tracks are unobstructed, or if it is necessary to obstruct these tracks they must obtain an order from the superintendent and must protect themselves by flag in the usual way.

Yard Masters.—These report to and receive instructions from the division superintendent (and also from the trainmaster or other officer in charge of transportation), and they also comply with instructions from the station agents. They usually have only to do with the handling of cars, but sometimes are also in charge of the track work of the yard.

Switch Tenders.—These report to and receive instructions from the station agents, while in yards they report to and are under the direction of the yard master or station master.

Bridge and Building Department.

This department is frequently connected more or less closely with the maintenance-of-way department. It has charge of the construction, maintenance and renewals of all structures, and one of the important occu-

pations of its superintendent should be the study of means for promptly rebuilding wrecked or damaged structures, and for replacing trestles, wooden bridges, etc., with solid banks and culverts or new iron structures. Turntables, track and stock scales, ash pits, water tanks, wells, pumping plants, mail cranes, coal handling machinery, etc., are frequently in charge of this department. There is usually a general yard for lumber and piles, while emergency stacks of timber are kept by the master carpenters at points on the divisions. This is a better arrangement than having a large stock on each division.

The department is generally in charge of a superintendent of bridges and buildings, who must inspect all the bridges once in three months, and all other structures under his charge once a year. He also tests and certifies as to the accuracy of all scales. He may report to the roadmaster or general superintendent, or to the division superintendent, the latter being the better plan, especially if the division superintendent is an engineer. Under the superintendent of bridges and buildings are the bridge foremen and their gangs, and sometimes the master carpenters. Further particulars of the work will be found in Chapter 21, under the heading of "Bridge Work."

CHAPTER 15.—TRACKLAYING AND BALLASTING.

The engineer in charge of tracklaying and ballasting has nothing to do with the location, but merely follows along upon the already completed roadbed, with the stakes already set, or he may have to put in the stakes for the tracklayers. He has to see that arrangements are made for keeping the contractor supplied with the proper amount of material, and also to see that the materials are properly used, and that the work is properly done. He should specially look after matters of detail, except, perhaps, in these now rather rare cases when a long line of track has to be laid with the greatest possible rapidity. As a rule the railway company supplies all material, and a supply train for delivering this material at the end of the completed line, ready for the contractor, who is in charge of the entire work of tracklaying (including the distribution of the material from the stated points of delivery), subject to the supervision of the company's engineer. Similar arrangements are made when the company does the work with its own men. It is to be noted that tracklaying is a work which requires a clear head, or good judgment, and a faculty for handling large bodies of men and keeping them all at work together without driving them or causing them to interfere with one another. This applies to the foremen as well as to the engineers, and it is further to be noted that tracklaying trains (like work trains) should be handled by powerful engines in good condition, and not by old engines which have outlined their efficiency for regular service.

The engineer is furnished with a copy of the field notes locating the position of each intersection, P. C. and P. T., the stakes by which these are referenced, and notes of the curvature and length of curve. In many cases he finds that the curves will not fit, and the P. C. must be moved back until the P. T. falls on the given tangent. Center stakes are driven at intervals of 100 ft. on tangents and 50 ft. on curves. Grade stakes are set opposite the center stakes, and at all changes of grade and at the

beginning and end of every curve. They are set on a line at right angles to the center line, two stakes being used on double track (each set at a distance from the center line equal to half the gage of the track), and one on single track. They are set on the inner side of curves. The roadbed must be properly leveled off to the grade stakes and have any hollows filled up before the ties are laid, this work being best done by the railway company, though very generally left to the contractor. The work should be done by a small grading gang, working ahead of the tracklaying gang, forming a compact and level surface for the ties, and working to the orders of an engineer, who can set out or check the center stakes, etc., not leaving this to the eye of a foreman. In some cases the roadbed is inclined on curves to approximately fit the superelevation, but this is not often practised.

The material train, with a properly arranged quantity of track supplies, is run to the head of the track, and the work is usually begun by hauling the ties by teams and distributing them alongside the roadbed. The tie gang then places the ties at right angles to the track (or radially on curves), spaces them accurately, locates the joints by a 15-ft. pole, picks out the large ties for joints where this is required, and then lines up the ties on one side of the roadbed by means of a cord stretched between stakes set half a tie length from the center line stakes. On curves this rope is first stretched as on tangents, and then curved by measuring the middle and quarter ordinates for the degree of curve. The ties should not be laid too far ahead of the rails or the joint spacing may be found to be incorrect, requiring rehandling of the ties under the rails, which is troublesome. The full number of ties should be laid at once, and not a few ties to each rail length, leaving the other ties to be slipped in under the rails, as the rails are likely to be kinked by the running of the material train over such a track. The ties should, if necessary, be adzed to give proper seats for the rails.

Rails are then run to the head of the track on a push car or horse car. The rail gang takes off two rails, half bolts them at the head joint, sets the head ends to gage at the front end by a grooved track gage, and secures them by a few spikes. It is usually specified that the rails must be laid with the maker's brand on one side (usually outside) of the track. If the rails are bent or kinked in handling they should be straightened before being laid, and all rails curved in a rail-bending machine for curves of over 2° or 3°. Care must be taken not to let the joints run ahead, but to keep them truly square, or else exactly opposite the middle of the opposite rail, according to whether track is laid with square or broken joints. To maintain this even spacing, some of the inner rails must have pieces cut off. A good plan is to have a number of rails cut to a length of 29 ft. 6 ins. at the mill, these short rails having their ends painted so that they can be readily distinguished. These rails are kept separate from the regular 30-ft. rails, and a certain supply of them is carried on the material train. The foreman of the tracklaying gang should then be provided with a list of the curves and the number of short rails required on each curve.

The joint or splice gang then bolts up the rail joints, and the spiking gang sets the rails to gage and completes the spiking. In this latter work the rails on the line side of the track should be spiked first, and used as the gage rail, and in all cases the outer spikes should be driven in the forward

side and the inner spikes in the rear side of the tie. The engineer should see that the proper widening of gage is given on curves (see "Gage" in Chapter 18). In bolting up the joints the specified spacing must be strictly adhered to, and only iron spacing shims should be permitted. The width of such spacing will be found in the chapter on "Rails." During this work care should be taken to see that spikes, bolts and other small material are not lost or wasted.

Any necessary tamping or filling under the ties is then done, and the ballast trains are then run upon the track and unloaded, and the ballast is put in place and tamped. Then comes the final lining, surfacing and dressing (described more fully in the chapter on "Maintenance Work,") the amount of care bestowed upon which depends upon the character of the road, but for first-class track, of course, all this will be carefully done. As few trains as possible should be run over a partly ballasted track, so as to prevent surface kinking of the rails, a defect which it is almost impossible to remedy subsequently. For this reason, the full tamping of the ballast should be carried on as each train load of ballast is distributed.

At sidetracks the switches and turnouts must be carefully laid out, and substantially supported on a good bed of ballast. The center stakes should be set for sidetracks, and the positions of head blocks indicated. The turnout curve may be laid out with a transit, or by means of a tape, with calculated offsets from the main track, as described in the chapter on "Switch Work." On bridges and trestles, where the ties are drift-bolted or otherwise secured to the stringers, the track centers may be marked by tacks at intervals of about 20 ft., and offsets made at the distance to the edge of the rail flange. A chalk line is then struck between these offset points, and in tracklaying the gage rail is first laid, with its edge set to the chalk line, and is then securely spiked, the other rail being set in position by the track gage.

For tracklaying by hand a convenient arrangement is to have a gang of 55 men in charge of two foremen, and equipped with three rail cars, one horse and two portable turntables. One turntable is placed at the loading and the other at the unloading end of the track. An ordinary load for the rail car is six rails, and a full supply of ties, splice bars, bolts, nuts, washers and spikes for that number of rails. If the driver reaches the front before the unloading gang has unloaded all the material from the first car he puts the turntable in position ready to haul the car off when empty, but if the gang finishes unloading before he arrives it runs the empty car off, ready to be hauled back. On returning to the loading end with the empty car, the driver puts the turntable on the track, and runs the car off onto a pair of ties. He then hitches the horse to the loaded car and goes to the front, while the loading gang runs the empty car back into position for loading. With such a gang of good men under a smart foreman a mile of track may readily be laid in two days. The distribution of the men is as follows:

9 men loading truck from construction train.
8 " unloading truck at head of track.
1 " with horse hauling the truck.
4 " spacing ties and lining them with a cord.
6 " splicing joints.
27 " spiking (3 sets of 9 men each).

The cost of tracklaying and surfacing (exclusive of ballast and ballasting) varies, of course, with the locality and the character of the track, but on Western roads it has averaged $250 to $500 per mile. One of the lowest records was that of the Atchison, Topeka & Sante Fe Ry., in 1888 ("Engineering News," May 25, 1889), when tracklaying at the rate of two miles per day was done with a gang of 164 men, at $170 per mile for tracklaying labor proper, and $60 per mile for surfacing, with a gang of 84 men; the total cost per mile, including expenses for engineers, engine and train crews, etc., was $247.77. Tracklaying on the Western Division of the Canadian Pacific Ry. was commenced June 1, 1882, and by Dec. 1 there had been laid 388 miles of main track and 30 miles of side track, west of Brandon. The greatest length laid in one day was 4.1 miles, and on three occasions four miles were laid in a day. The best speed on record was half a mile of track laid in 35 minutes. The rate of progress is given in the following table, from the Proceedings of the Institution of Civil Engineers, 1883-84:

Month.	Working days.	Miles laid.	Miles, pr day.	Month.	Working days.	Miles laid.	Miles, pr day.
June	26	68.70	2.64	October	26	59.38	2.28
July	26	63.56	2.44	November	26	38.30	1.47
August	27	86.86	3.22				
September	26	71.25	2.74	Total	157	388.05	2.47

The tracklaying gangs on the Canadian Pacific Ry., where fast work was done, were composed as shown in Table No. 17.

TABLE NO. 17.—TRACKLAYING GANG; CANADIAN PACIFIC RY.

Unloading rails from cars*	12	Teams hauling ties	33
Loading rails on trucks*	12	Unloading and distributing ties	8
Unloading and laying down rails*	24	Spacing ties	4
Bolters	15	Readjusting displaced ties	2
Spikers	32	Rail truck boys (to 6 horses)	4
Nippers	4		
Spike peddlers and tie loaders	32	Total	182

*Eight men in each of these gangs were handling joints, bolts, etc.

The following is a detailed description (taken from an article written by the author and published in "Engineering News," New York, Nov. 14, 1895) of the train and methods of work employed in 1892-1893 in the construction of the extension of the Minneapolis, St. Paul & Sault Ste. Marie Ry., from Valley City, N. Dak., northwest across North Dakota, 263 miles, to connect with a branch line which the Canadian Pacific Ry. was then building southeast from Pasqua (on the main line) to Portal, on the United States boundary, 160 miles.

The track is laid with 30-ft. rails, weighing 72 lbs. per yd., spiked to cross-ties 6 ins. thick, 7 to 10 ins. wide and 8 ft. long, spaced at the rate of 2,816 to 2,992 per mile, or 16 to 17 per rail length. The rails have square three-tie supported joints, spliced by 40-in. angle bars with six ⅞-in. bolts, spaced 6, 6½, 7, 6½ and 6 ins. c. to c. The engineer did not approve of this joint, and questioned the utility of any splice bar exceeding 22 to 26 ins. in length. On the older track, south of Valley City, the track has suspended joints, with joint ties 7 ins. apart between faces, and the rails spliced by 23-in. Samson angle bars, with four bolts spaced 4½, 7 and 4½ ins. c to c. The width at subgrade is 16 ft. The tracklaying and surfacing were done by the railway company.

The entire construction train was made up of 32 cars, as follows:

1. Pioneer car.
2. Store car.
3, 4. Dining and sleeping cars.
5. Kitchen car.
6. Dining and sleeping car.
7. Feed car.
8. Water car.
9 to 16. Flat cars with rails and spikes.
Locomotive.
17. Telegraph material.
18 to 32. Box cars with ties.

Cars No. 1 to 8, both inclusive, formed the boarding or work train, which was always kept at the head of the track. The material train, composed of cars Nos. 9 to 32, both inclusive, was brought up during the night from the last side track, and stopped so that the interval between cars Nos. 8 and 9 was about 400 ft. The tie cars, Nos. 18 to 32, were then cut off at the coupling between Nos. 17 and 18, and the rail and telegraph cars were moved up and coupled to the boarding train, making the train as described.

Work commenced at 7 a. m., the teams then beginning to haul ties from the five rear cars onto the grade (which had a top width of 16 ft.), where the tie men helped to unload, place and space them. The tie wagons

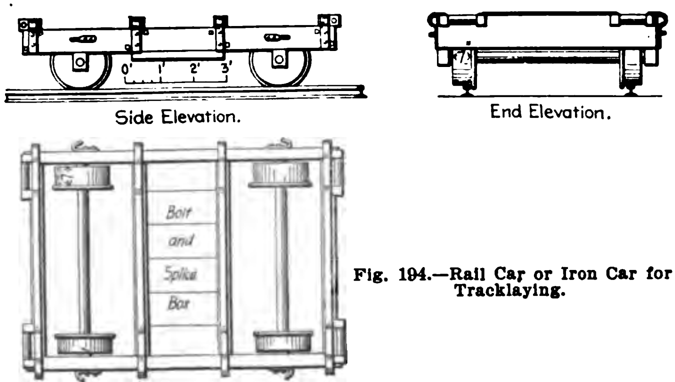
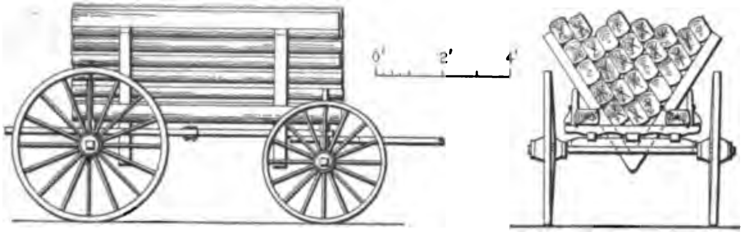


Fig. 194.—Rail Car or Iron Car for Tracklaying.

are shown in Fig. 191, and the chutes for loading them with ties from the box cars are shown in Figs. 192 and 193. One hundred rails and the necessary fastenings were unloaded from both sides of cars Nos. 15 and 16, dropping onto the soft earth of the roadbed, and the train then moved back 400 ft. The rails were handled by means of rail forks, Fig. 172. The 100 rails were then loaded on two iron cars, Fig. 194, each carrying 50 rails, and being "trimmed" with splice bars, bolts and spikes. The iron cars were then hauled to the end of the track by horses. Ten men on each side of the leading iron car ran forward with a rail and dropped it in place, together with a pair of splice bars and six bolts for each joint. Immediately the rails were dropped, one man threw a hook gage, Fig. 195, over them, near their outer ends, and the horse then pulled the car forward 30 ft., one man on each side stopping and blocking the car wheels with an



Side Elevation.

End Elevation.

Fig. 191.—Tie Wagon.

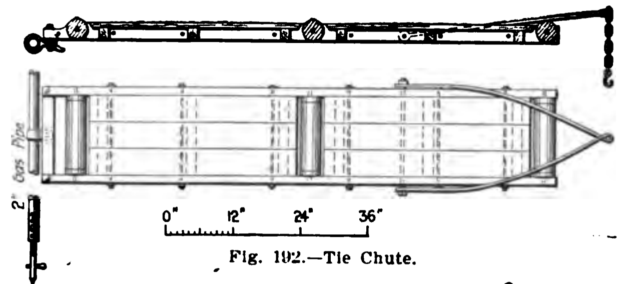
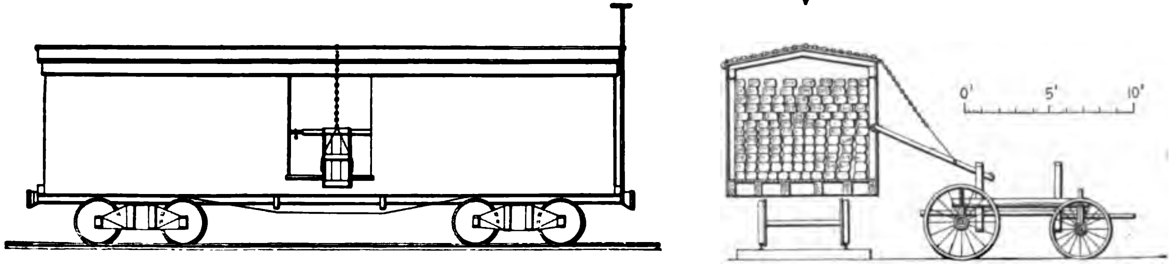


Fig. 192.—Tie Chute.



Side Elevation.

Cross Section.

Fig. 193.—Unloading Ties by Chute.

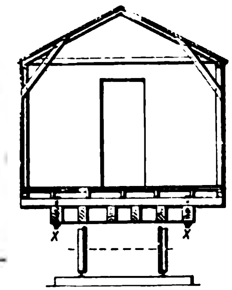


Fig 198.—Kitchen Car.

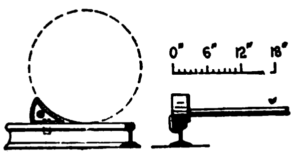


Fig. 196.—Stop Block for Rail Cars.

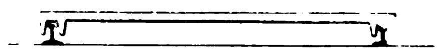


Fig. 195.—Tracklaying Gage.

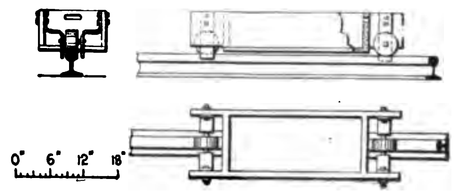


Fig. 197.—Spike Peddlers' Car.

TRACKLAYING APPLIANCES ON THE MINNEAPOLIS, ST. PAUL & SAULT STE. MARIE RY.

iron stop block, Fig. 196. Two more rails were then quickly run out and dropped, as before. At every fifth and sixth rail length, alternately, a 200-lb. keg of spikes was thrown off, containing about 375 spikes 9-16 x 5½ ins. These kegs were broken open by the two spike peddlers, who took 100 lbs. of spikes in their car boxes, Fig. 197, and placed two spikes on each tie where it was crossed by a rail.

The tie-wagon, Fig. 191, was a four-wheel wagon, with two V-shaped supports to hold the ties, the capacity being about 25 ties. The tie chute, Fig. 192, was a plank platform with three rollers; the inner end was attached to a transverse bar of 2-in. gas pipe, placed at any desired height across the car door and secured by turning the pointed screw at one end; the outer end was supported by an iron sling and chain from the roof of the car. Fig. 193 shows the method of attaching and using the chute. The iron car, or rail car, Fig. 194, had two longitudinal sills and four transverse sills, with planks nailed across the bottom of two of the latter to form a box for splice bars and bolts; the wheels were 20 ins. diameter and 7 ins. wide on the tread, and two rollers were fitted at each end in the usual way; each car could carry 50 rails of 72 lbs. per yd. The hook gage, Fig. 195, was used to hold the free ends of each pair of rails as laid, while the iron car was run onto these rails and stopped by the block shown in Fig. 196. The spike peddlers' car, Fig. 197, was a handy little device, running on one rail and carrying about 100 lbs. of spikes, so that the spike peddlers could distribute the spikes very rapidly. The double-deck dining and sleeping cars were 34 ft. long over the body with a 3-ft. platform at one end; the width of the body was 12 ft., out to out, and the dining room and sleeping room had each a clear headway of 6 ft. 3 ins.; the sleeping room had two rows of berths on each side. The kitchen car, Fig. 198, was of similar dimensions, but had only one floor. In both of these cars the bodies could be removed by unbolting the four corner bolts, X X, which secured the end floor beams to the outer sills of the car frame.

The two "front strappers" put on the splices, adjusted the expansion spacing by metal shims, and fastened the two center bolts, the other strappers following and completing the joints. Four "front spikers" with a gage followed close on the front strappers, and spiked the track at joints, centers and quarters, while 12 other spikers finished the spiking. For each two spikers there was an assistant, called a "nipper," who held the tie up to the rail with a nipping bar, using a block as a fulcrum. When the rails on both iron cars were nearly all in place, the train was again run forward, and 100 rails and the necessary fastenings thrown off as before, and the train again run quickly back out of the way. The iron-car gang would "drop" 100 rails (1,500 ft. of track) in from 25 to 30 minutes. Tie cars were brought forward at about every second move of the train, or oftener if the nature of the ground required it.

At about 11:30 a. m. the ties remaining in the box cars were thrown out on the ground, to be picked up and loaded on the wagons, while the empty cars, Nos. 9 to 32, both inclusive, were run rapidly back to the nearest side track and exchanged for loaded cars arranged as before, these being brought to the front in time for work at 1 p. m. An additional locomotive, pushing at the rear of car No. 32, was employed when the grades required it.

Telegraph material was thrown off car No. 17 at each forward movement

of the train. The poles were of cedar, 6 ins. diameter at the small end and 25 ft. long, set 5 ft. in the ground, and these were spaced 30 to the mile. The wire was stretched from a reel placed on a small hand wagon, pushed by men. Tents were carried on the boarding train to be set up at night for quarters for extra men, or to shelter the horses in cold weather. Detachable feed boxes were slung on the sides of the boarding cars. The general foreman had control of all trains and employees working at the front, and in cases of emergency could at any time communicate by telegraph with the superintendent of construction, a few miles at the rear. Material tracks from 2,000 to 2,500 ft. long were laid at intervals of about 10 miles, unless regular stations were to be provided at shorter distances.

Surfacing gangs, who lived in boarding cars set off on temporary side tracks, followed the tracklayers, and surfaced the track from the shoulders of banks or sides of cuts, so as to make a safe roadway and prevent bending of the rails or splices before the ballasting was done. These gangs usually numbered 40 to 45 men under a foreman and sub-foreman. About 250 men were required, and they went to and from work on hand cars.

Mr. Rich, the Chief Engineer, states that the company has laid much track with several of the tracklaying devices in use in this country, and in swampy, very hilly, or timbered regions they were very serviceable, but in a dry, open country like North Dakota the method above described enabled the work to be advanced at double the speed and at no greater cost per mile. The average advance was three miles per day, and on one or two occasions in 1893 over four miles of track were laid in 10 hours with the force named below, and by increasing the force without regard to strict economy, five or six miles might be laid in a day.

The entire work was in charge of a Superintendent of Construction, stationed at the siding nearest to the "the front," or the head of the track, who ordered and forwarded material and gave general instructions. He had a business car, a clerk, who was also a telegraph operator, and a cook. The telegraph line was in working order at the end of the track every night, the instrument and operator being located in car No. 1. The tracklaying force was as given in Table No. 18.

TABLE NO. 18.—TRACKLAYING FORCE; M., ST. P. & S. S. M. RY.

	Foremen.	Laborers.
General foreman, on horseback	1	..
Iron car gang (who dropped rails and fastenings)	1	22
Strappers (adjust & bolt splices).	..	6
Spike peddlers (distribute spikes)	..	2
Tie-spacing gang	1	12
Men lining ties (rope and stakes)	..	2
Men spacing joint ties (with 30-ft. pole and tie pick)	..	2
Men leveling grade cut by tie wagon	..	4
Spikers	..	16
Nippers (hold up ends ties for **spikers with blks & nipping bars.**	..	8
Tracklining gang	1	6
Teamsters for tie wagons	1	40
Men unloading ties from cars (3 to each car)	..	15
Men unloading rails and fastenings from cars	..	4
Telegraph gang	1	8
Telegraph operator	..	1
Drivers of iron-car horses	..	2
Blacksmith	..	1
Night watchman	..	1
Cooks	..	2
Baker (who worked only at night)	..	1
Waiters and helpers	..	5
Storekeeper	..	1
Total	6	161

All baking of bread and pastry was done during the night by an extra force of cooks. The cooks, baker, waiters, helpers and storekeeper were employed by a contractor, who boarded the men for $3.50 per week, fur-

nishing all supplies and bedding. The amount for board was deducted from the wages of the men and paid to this contractor.

Returning to the details of the train and equipment, the make-up of the entire train has already been described. The equipment and capacity of the boarding train, kept at the head of the track, was as follows:

No. 1. Pioneer car, double deck. This contained a blacksmith shop, 10 × 12 ft.; storeroom, 8 × 12 ft., for heavy tools, harness, etc.; office for general foreman, 12 × 14 ft., with three sleeping berths and telegraph office; two sleeping apartments on the upper floor, and a tool box under the car. In front of the car was a platform supported by rods from the top, carrying extra splice bars, bolts, and spikes, and under the platform was fastened an extra iron car for emergencies.

No. 2. Store car, double deck. This had a storeroom for clothing, shoes, tobacco, etc., and another for provisions; sleeping berths for the cooks, a sleeping apartment above and a tool box underneath.

No. 3. Dining and sleeping car, double deck. On the lower floor were two dining rooms, one for the foremen and guests, the other for teamsters and telegraph gang. Above were separate sleeping apartments for the teamsters and the telegraph gang, and underneath was a tool box.

No. 4. Dining and sleeping car, double deck. On the lower floor was the laborers' dining room, and above was a sleeping apartment, with berths for 32 men. Underneath was a tool box.

No. 5. Kitchen car. This had a kitchen and provision room, 12 × 32 ft., with two cooking ranges. Underneath was a water reservoir supplied by hose from the water car (No. 8), while pumps in the sinks delivered the water as needed by the cooks. This car has no upper deck. (Fig. 198.)

No. 6. Dining and sleeping car, double deck. On the lower floor was a laborers' dining room, and on the upper floor was a sleeping apartment with berths for 32 men. Underneath was a box for wood for fuel.

No. 7. Feed car. An ordinary box car, 8 × 34 ft., carrying feed for the horses and coal and wood for the use of the cooks.

No. 8. Water car. A flat car, having at each end a wooden tank of 2,000 gallons capacity, the tanks being connected by a pipe.

No. 9. An ordinary flat car, loaded with rails, bolts and spikes.

No. 10. (Car No. 17). An ordinary flat car, loaded with telegraph material.

Tracklaying by Machinery.

While tracklaying machines have been very extensively used on large railway contracts, mainly in the western states, comparatively little is known by engineers generally of their operations. The common system of tracklaying is to have the ties hauled onto the grade by teams, and the rails run forward on small hand cars. For long stretches of work, however, and in difficult country (rugged or swampy), especially where teams cannot be used to distribute the ties ahead in the usual way, machine tracklaying is very extensively employed and permits great rapidity, with a saving in cost over the ordinary method. The title "tracklaying machine" is rather an incorrect one, since the machine does not lay the track, the general principle of the system being that the ties and rails are run to the front of the supply train on rollers or tramways laid along the cars, and are delivered to the tracklaying gang from a frame projecting in front of the first or pioneer car, this car or "machine" forming the head of the

material train, which is pushed forward as fast as the track is laid, moving one or two rail lengths at a time. The supplies for a day's or half a

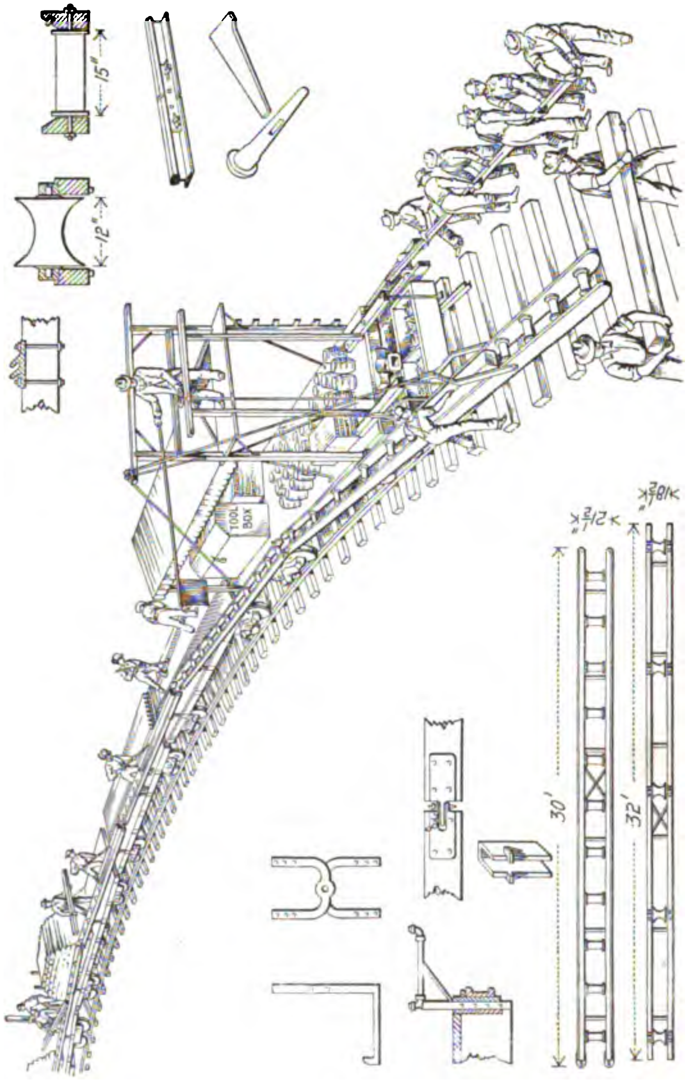


Fig. 199.—The Holman Tracklaying Machine.

day's work are carried on the material train and delivered right where wanted, the train being moved up 30 or 60 ft. at a time, according to whether the rails are laid singly or in two-rail lengths. It is not uncommon practice to lay only half the number of ties to a rail length ahead of the train,

leaving the rest to be put in by a tie gang following the train, thus somewhat reducing the close work of a large gang, but while a single train may perhaps not do very much damage to a half-tied track, it is, as a rule, better practice to put in the full number of ties before the train runs over the track.

The quality of the work depends upon the speed of operation and the method of working. In some cases the whole number of ties for each rail is laid ahead of the train, while in other cases only half the number are laid, and the balance are slipped in endways by a rear gang following the train. As a general principle it is always best to get the full number of ties laid ahead, as a better track is obtained in this way, and there is less liability to injure the rail by surface kinking. Descriptions of three forms of tracklaying machines, with details of the methods of operation, are given herewith, taken from an article by the author in "Engineering News," New York, of Jan. 3, 1895.

The Holman tracklaying machine, Fig. 199, is composed of a series of tramways 30 ft. long and about 20 ins. wide, fitted with heavy iron rollers, and these tramways are attached to the sides of ordinary flat cars, without any changes, being supported by adjustable iron stakes that fit into the pockets on the sides of the cars. The sections are connected and operate the full length of the train, as continuous inclined tramways. The ties and rails on the supply cars are thrown upon these tramways and rolled down to the front, where men receive and place them in position on the roadbed. The ties come down on one side of the train and the rails on the opposite side. The tie tramway ends in a chute, supported by a wire cable, which runs out 35 ft. in front of the train, so that the men handling the ties are one panel ahead of the rail men, and consequently the gangs are out of each other's way. As each rail comes down the chute it is seized by the rail men, placed on the ties and pushed back against the end of the last rail, the expansion spacing being arranged by the joint gang.

The pioneer or pilot car at the head of the train is fitted with an elevated frame or trestle, from which the chutes forming the end of the tramways are suspended, and on this frame rides a brakeman who signals the engineman when to push ahead, and attends to the brakes on this car. The splice bars, bolts, and spikes are carried on the pilot car. A train of ten cars (six cars of ties, three cars of rails, and the tool car) will carry all the material required for a half-day's work and from half to three-quarters of a mile of track. From 1¼ to 1½ miles of track per day can be laid with this machine, or even two miles with from 40 to 60 men, provided the railway company can deliver the material at the front fast enough, and in proper shape. This includes the full supply of ties, laying the rails in position; joint, quarter and center spiking; putting on the fish-plates or angle-bars, and putting two bolts through the same. This leaves the track in safe condition for the construction train to pass over, and the balance of the work is finished behind the train without reference to or use of the train. As fast as the panels or rail lengths are laid, the train moves forward 30 ft. at a time, carrying all material with it, leaving nothing scattered along the line. The main objects of the machine are to dispense with the use of teams in the distribution of material and to reduce the cost of railway building, both of which it does effectually, and it is claimed that from $50 to $200 per mile can be saved by its use.

The patents on this machine are owned by Mr. D. F. Holman, of Chicago, Ill.

The engineer's report of tracklaying done with one of these machines by Mr. Nelson Bennet on the construction of the Cascade Division of the Northern Pacific Ry., on March 30, 1886, showed that the amount of track laid was 8,400 ft. Actual time occupied in laying, 8 hours. The track was laid in strict accordance with the specifications, full tied, full bolted, full spiked, ties accurately spaced, the track properly lined to center, and expansion spacing attended to. The working force comprised tracklaying machine, 1 foreman and 66 men, distributed as follows: In front of the machine: 1 tie man, 8 tie carriers, 2 bolters, 4 spikers, 1 chute man, 6 rail carriers, and 2 nippers. On the train: 2 men unloading rails, 2 men pushing rails, 16 men handling ties. Behind the train: 2 spacers, 8 spikers, 3 bolters, 4 nippers, 4 liners and 1 spike peddler. On this day the boarding train was about five miles in the rear, two hours were consumed in going to and from work, and making up train, leaving 8 hours actual working time. Experience with the tracklaying machine showed that good work could be done as cheaply and speedily as poor work. Where the grade was freshly trimmed, a gain of 1,500 ft. per day in tracklaying could be made. He was satisfied that under favorable circumstances 100 stations could be laid in a day of 10 hours.

Another of these machines was used on the Pacific extension of the Great Northern Ry., and during the short days of the winter of 1890-91 the contractors laid with it in 82 days an average of over 1¼ miles of track per day, and in 25 days laid within 1,000 ft. of 50 miles. The most of this work was done in November and December, and under the usual disadvantages attending work at that season of the year. Mr. N. D. Miller, Chief Engineer of the Great Northern Ry., stated that in timber or broken country, where it is difficult to get in with teams to lay ties, the work can be done cheaper with the Holman machine than it can by handling the ties. The machine can be used to advantage to lay from 1¼ to 2 miles per day. If necessary to lay more than this (which would be exceptional) as a general thing, it would be cheaper to lay by hand, using hand or rail cars, although on this road they have laid as much as three miles per day with one of these machines, but the track was not fully spiked or tied. To lay from 1½ to 2 miles per day about the following force would be required:

48 tie men,
8 iron men,
9 nippers,
8 spike peddlers,
12 wrenchers.
1 shim peddler,
16 spikers (or 18 if there is much curvature),
16 men handling iron on the cars and carrying it to the front.

They would require about nine cars of ties and six cars of rails. On the light grades one engine could handle this outfit, a supply train bringing the material to the nearest siding to where rails are being laid. This is only a general estimate, varying according to the ground and the kind of roadbed. On ordinary work he considered it cheaper to lay with the machine than with iron cars, while the roadbed is in better shape for the track than it would be where ties are hauled by team.

The Burlington & Missouri River Ry. has laid its own track for the last eight years, and its last contract for tracklaying by hand, before that time, was let at $300 per mile, which included loading track material and higher wages than these now ruling. Both the Holman and Harris track-

laying machines have been used, and the former was used on the Billings extension, built in 1894. According to Mr. I. S. P. Weeks, Chief Engineer, the speed of the Holman machine, with a force of 85 men, was 1¼ miles per day, which is the most convenient speed, and the cost at such rate was about $100 per mile. For this rate there was a morning and an afternoon train, each made up of four flat cars of rails and four flat cars of ties ahead of the locomotive, and four box or flat cars of ties behind the engine. On the Billings extension the track was laid with 65-lb. rails, and 18 ties to a rail, or 3,168 ties per mile. The track was half-tied in front of the engine, the balance of the ties being put in by lifting the rails and dragging the ties into place endways. Curves of 1° to 16° were laid without any special arrangement. Mr. Weeks stated that, if it should be desirable to lay 2½ miles of track per day, it could be done by working two shifts of men with the Holman machine, laying 1¼ miles each in the morning and afternoon. With the Harris machine, he has laid 2½ miles per day on a spurt, when ties were distributed ahead of the track. This machine has been used with very satisfactory results, and at about the same expense as the Holman for a rate of 1½ miles per day. With the Holman machine there were 86 men, distributed as shown in Table No. 19.

TABLE NO. 19.—TRACKLAYING GANG WITH HOLMAN MACHINE; B. & M. R. RY.

43 Men in Front of the Engine,
1 foreman,
1 heeler,
4 spikers,
2 nippers,
1 rail thrower,
1 spike peddler,
1 gage carrier,
1 expansion driver,
2 fork men,
4 rail pullers,
1 water boy,
1 line man,
1 pole man and marker,
4 tie carriers,
2 tie spacers,
1 tram tender,
1 bolt trimmer,
2 bolters,
2 strap carriers,
8 tie pushers,
2 tie loaders.

43 Men Behind The Engine,
1 straw boss,
2 tie unloaders,
2 tie placers,
4 tie spacers,
2 rail lifters,
12 spikers,
6 nippers,
2 spike peddlers,
4 bolters,
1 gage carrier,
1 water boy,
2 spike pullers,
4 liners.

With the Harris tracklaying machine ordinary 34-ft. flat cars are used, with four or five bridge ties, 6 x 8 ins. and 11 ft. long, laid across the floor, at proper intervals, and bolted to place. Ordinary 30-ft. rails are spiked to these at about 8 ft. or 8 ft. 6 ins. gage. Fish-plates are attached to the ends of the rails by a single bolt through the end hole in rail, and end holes in plates, thus causing the plates on adjacent cars to project toward each other as far as possible. The gap in the track between cars is then filled by short rails, having 18 ins. of the base cut off at each end, to permit of dropping the web into the slots formed by the projecting plates attached to the ends of the fixed rails on each car. These connecting rails are cut short enough to avoid jamming when all slack in car couplings is closed up to the minimum. Ten pairs of the short rails will equip a train of material, and they are always retained at the front, for use on each train while unloading. Along the middle of each car carrying rails are four or five iron rollers, 3½ x 10 ins., attached to the cross-ties along the deck of the car, forming a runway for conveying rails to the front. The rails are loaded in two neatly made piles, one on each side of the car, so as to clear the rollers in the middle and the tram rails on the sides of the car, the middle runway being about 24 ins. wide. Each car carries the proper complement of splice bars, stored in the open spaces between the cross-ties, while spike and bolt kegs are loaded in the runway between the rail piles and are afterwards moved to the end of

the car, preparatory to unloading when the train reaches the front. The cars for the ties have the tramway, but no rollers. The front or "pioneer" car, besides being fitted with the rail rollers and tie tramway, has a frame of long stringers attached to the front end, to extend the tram track about 15 or 20 feet ahead of the car. The front ends of the stringers are supported by truss rods, extending over a light trestle 10 ft. high, near the middle of the car, and securely fastened at the rear end of the car. A stout cross-beam on the front end of the stringers has a short timber extending downward in middle, to support a double-ended roller about 2 ft. below the level of car deck. Two portable "dollies" are used at intervals of 15 ft. ahead of the car, placed in the center of the roadbed. These are light trestles or towers, about 3½ ft. high, with a roller about 4 x 18 ins. on top of each. The 8-ft. gage truck or tram, for conveying the ties forward along the tram and dumping them at the front, has a platform about 5 x 9 ft. and is fitted with a double frame, so arranged that the top frame is permitted to slide forward on rollers about 3 ft. when the wheels strike the chock block on the front end of the dumping frame in front of the pioneer car. This shifts the load forward, causing the car to tip downward in front, so that the load slides off onto the roadbed, after which the car tilts back level, and the men slip the top frame back to its normal position, while returning for the next load of ties. Owing to the width of this tram the men on the rail cars have to move back onto planks laid on the ends of the 11-ft. ties to let it pass. Another truck with a plain single frame is used to good advantage in conveying ties part way from the tie cars to the front, the load being transferred to the dump car at the meeting point. This second car is a little higher than the dump car, to permit of transferring the load by simply sliding the ties from the higher car to the lower one. These tie trams and the pioneer car are always kept at the front end of the track. Material for a mile of track is loaded on 15 cars behind the pioneer car, as follows: 5 flat cars carrying 72 rails each, 5 flat cars carrying about 300 ties each, and 5 (sometimes 7 or 8) box cars with a total of about 1,500 ties. The engine is placed at the rear and the train pushed to the front, with the cars arranged in the order named. After coupling to the pioneer car, the short connecting rails are adjusted in the tie-tram track, spike and bolt kegs are taken from the runway and stored on the ends of the cars, and the tie-tram is run back to the cars and loaded. One man with a rail fork throws two rails from each of two of the rail cars onto the rollers, when four men pull these four rails forward to the pilot car, where two more men on the rear end put on the splice bars and two bolts, and put in the expansion shims. The man on the rail car also throws off the splice bolts and spikes, as required. Meanwhile 16 to 18 ties (for two rail lengths) have been loaded on the tram and the rail men step aside to let it pass, as it runs out onto the frame beyond the pilot car and dumps its load onto the ground, when the tie men distribute them over 60 ft. of the subgrade. When the tram is run back, the four rails bolted together are run forward over the dumping frame rollers onto the portable "dollies," until the rear ends are clear of the car. The rails on the line side are then lifted from the rollers and dropped on the ties, thrown back against the rails already laid, and fastened to the latter by one bolt through the splice bars previously bolted to them. While the gage rails are being laid in the same way 4

men are spiking the line side at 3 or 4 ties per rail (quarters and centers), and 4 more follow with gages and spike the gage rail. At the same time 2 men are putting expansion shims at the heel joints of the two-rail section and half-bolting up these joints, and 2 more are putting the splice bars on the front end of the section, while others are moving the dollies ahead. A flagman near the front end signals the engineman when to stop and start, and the train is now moved ahead 60 ft., bringing the front end of the pilot car about 8 ft. from the end of the last rail, when another load of ties is dumped as before.

Meantime, a few men in two of the box cars at the rear of the train drop off eight or nine ties per rail length at each move of train, while a man on the ground alongside sees that the ties do not go down the embankments, and also that no more or less than the proper number are dropped off. A few men with picks and four quick-working ratchet jacks follow immediately in the rear of the train, putting in the back ties, and those are followed by the back bolters, spikers and lining gang, who complete the work in the rear as fast as it is strung out at the front. In other words, track is only half-tied, half-bolted and quarter-spiked in front of train. Material to complete the work is distributed from the train as it advances, and the back gang keeps the work completed close up to the rear of the train. This machine is operated by the Harris Co., of Chicago, Ill. For laying track with broken joints, the ties are carried 15 ft. further ahead, and the four rails (two lengths of two rails each) are run out as usual. The line rails are dropped into place. The gage rails are run out 15 ft. further on the rollers of the dollies, then dropped into place and heeled back into the angle bars of the rails already laid. This is done while the line spikers are spiking their first tie, so that no time is lost, as the gage spikers start their work as soon as the gage rail is in position.

For quick work two tie trams may be used when the front cars of ties are unloaded, the front one being the dump tram, and each load being transferred from one tram to the other. This plan, with a long train, is said to save two hours a day and to enable 2,000 ft. more track to be laid than with one tram. With this system of working, as above described, the organization of force for laying two miles of track per day on the Chicago, Kansas & Nebraska Ry., in 1887, was as follows:

On the train: 2 bolters, 4 or 6 rail pullers, 1 man throwing rails on rollers and dropping off bolts and spikes, 6 men handling ties and running the tram (or 8 men with two trams); 13 to 17 men in all. In front of the train: 8 spikers, 4 nippers, 12 rail men, 2 bolters, 2 men moving the "dolly," 1 handling the tie line, 1 handling the 30-ft. pole and marking the ties, 1 spike peddler, and 1 water boy; 31 in all. Behind the train: 4 bolters, 12 to 14 men with two track jacks and some picks, pulling in and spacing the additional ties, 16 to 20 spikers, 8 to 10 nippers, 5 liners, 2 spike peddlers, 1 tie marker and 1 water boy, or 49 to 57 in all. The complete crew would consist of 1 general foreman, 1 heeler acting as foreman of the front gang, 1 foreman in charge of the back spikers, 1 foreman of tie gang, 1 sub-foreman lining track and 100 to 115 laborers. The tie markers carry a measuring board, which they place on the line end of every tie and strike a chalk line across, 16 ins. from the end of the tie, to guide the spikers in keeping ties in line.

With four quick bolters in front, easy-fitting bolts, and a well-trained

front gang, a 60-ft. section, or "set-out," was often laid in 2½ minutes for hours at a time, the train being moved up as fast as the men could handle the material. Owing to delays in switching and running to and from work, the force never worked 10 hours consecutively, but over two miles of track were usually laid in 9 hours' steady work, and some of the records were as follows: 1,300 feet in 30 mins., 5,600 feet in 4 hrs. 5 mins., 11,100 ft. in 8 hrs. 30 mins., and 11,000 ft. in 8 hrs. 55 mins. It was estimated that over 12,000 feet could be laid in 10 hours, at a cost of $240 for gang and foremen; adding to this the cost of motive power and trainmen and the expense of loading cars, the cost was estimated to be somewhat less than $150 per mile. The half-tieing is, of course, a disadvantage.

The Chicago, Rock Island & Pacific Ry. constructed about 1,300 miles of track with the Harris machine in 1886 and 1887, the results being satisfactory in point of cost, speed and quality of work. Mr. D. Sweeney, Division Roadmaster (who was in charge of the work on the C., K. & N. Ry., above noted), has given the following detailed particulars:

"It requires not fewer than 100 men to work this system to its full capacity, which is a little upward of two miles per day. The front bolters must be sufficiently expert to splice a joint with two bolts moderately snug in every 2¼ minutes; failure on their part will delay the entire work. Rail pullers and tie-tram men must be lively workers, but the men on other parts of the work can keep up by moderate effort. The average cost of laying two miles of track per day by this method is about as follows:

1 general foreman, av. rate,	$5.00	$5.00	1 eng. and tr'n crew, av. rate,	20.00	20.00
2 assistant foremen, " "	3.00	6.00			
109 laborers, average rate..	2.00	218.00	Total for two miles		$249.00

"To this must be added a small amount per mile as royalty for use of the 'machine,' and about $10 per mile for preparatory work in transferring material to the cars in the yard, all of which will bring the actual cost to about $140 per mile where work is properly handled and not subject to much interruption or delay.

"The Chicago, Rock Island & Pacific Ry. has also constructed about 200 miles of track with the Holman machine during the past few years. This was done in a leisurely way and in short patches that did not justify equipping cars for the Harris system. The general work of the Holman system has already been described, but on the C., R. I. & P. Ry. the track was not full-tied ahead of the train. After 8 or 9 ties were delivered and spread on a 30-ft. section of roadbed, the rails were heeled to place, one at a time, and spiked to four ties, the train being then moved forward 30 ft., and the process repeated until material runs out. The back tieing and finishing up were done in the same manner as with the Harris machine. The average capacity of this system was about one mile per day with 60 to 70 men, which is about as many as it will employ to advantage. Following is approximate cost of work per day:

1 general foreman	$5.00	$5.00	1 engine and train crew..	20.00	20.00
2 assistant foremen, each	3.00	6.00			
70 laborers, each	2.00	140.00	Total for one mile.............		$171.00

"It will be seen here that it cost as much for train and foremen in laying one mile with the Holman as it does to lay two miles with the Harris. Still, the Holman is the more economical for short stretches, or in cases where tracklaying is subject to frequent delays awaiting material, or the

completion of grading and bridges. The gang is comparatively small, has few places requiring specially-trained men, and would be subject to little loss or demoralization in changing from tracklaying to surfacing, and vice versa. It is probable that the capacity of the Holman machine could be largely increased by making slight changes in the machine and method of working it. But either of these machines will lay track more economically than it can be done with iron cars. The system does away with the heavy expensive team work and cutting up of the roadbed incurred in hauling ties ahead of the track. It also prevents leaving large piles of surplus material scattered behind the tracklayers to be afterwards picked up at considerable expense, or else wasted.

"A considerable saving in time and expense can be effected in any system of tracklaying by only half tieing in front of the construction train and having the balance of ties dropped systematically from the train, so as to place opposite each rail length the exact number required for completing each panel of track. This lightens the work and increases the headway of the front gang, and materially speeds up the entire work. People who are accustomed to laying the full complement of ties and bedding them under a straight edge before rails are laid, will fear that this method would lead to the rails becoming surface bent, etc. I used to feel that way myself until convinced by experience that with a smooth roadbed, ties of fair average size, and a steel rail of not less than 60 lbs. per yd., there is no danger of material damage to the rails by the method suggested. Of course, an occasional exceptionally thick tie should be laid aside by the front gang and bedded in by the back gang. The track should also be surfaced as soon as possible after it is laid. Tracklaying machines do not work as well on curves as on straight track, and I would not recommend them for work on very crooked or very hilly roads. Nor is it advisable to adopt the Harris system for less than 100 miles, or the Holman for less than 50 miles of work. The following is an approximate estimate of force and expense in laying track at the rate of two miles per day by the old style iron car method:

1 general foreman	$5.00	$5.00	1 team hauling iron cars.	4.00	4.00
5 assistant foremen	3.00	15.00	1 engine and train crew..	20.00	20.00
160 laborers	2.00	320.00			
22 teams hauling ties...	4.00	88.00	Total for two miles		$452.00

"Of course the expense in all methods will vary in accordance with the rate of wages allowed to employees, and each method must have sufficient force to work it to its maximum capacity in order to attain the best results."

As to the questions raised in regard to half-tieing and to work on curves and hilly work, it is by far the best practice to put in the full number of ties at once, and the evidence from other roads seems to indicate that the machines are adapted for work in rough country, with sharp curves and steep grades.

The special feature of steam tracklaying machines is that the ties and rails are run to the front on tramways having rollers operated by steam power. In the Roberts machine, made and operated by the Roberts Steam Tracklayer Co., of Seattle, Wash., there is a series of chutes or tramways, with live rollers, extending along each side of the train. These tramways are in sections about 32 ft. long, the alternate rollers being driven by a shaft extending the whole length of the train and fitted with universal couplings so as to allow for the motion and curvature of the train. The two

shafts on the front or pioneer car are driven by gearing by a vertical engine near the front of the car, and having powerful friction clutches, which will give, and so prevent fracture in case of any obstruction stopping the shaft. The engine is supplied with steam from the locomotive. The rails are sent down on one side of the train, and the ties on the other, the ties being delivered about 60 ft. ahead of the car, so that the tie gang is out of the way of the rail gang. The rollers of each tramway can be operated separately or together. The live rollers of the tie tramway have corrugated surfaces so as to bite the tie and force it along, the intermediate rollers being dead rollers about 1 in. below the live ones. The end chute of the rail tramway projects about 6 ft. beyond the car, so that the bolting up of the heel joints is not interfered with by the car. The tramways are carried by brackets inserted from the bottom of the stake pockets of ordinary cars, so that ties projecting beyond the edge of the car do not interfere with the tramways. The rail cars are placed in front of, and the tie cars behind, the locomotive, and brakes are partly set on the front and rear cars, so as to take up the slack of the train. A small whistle on the stationary engine serves as a signal to the man on the locomotive.

Only a small portion of the front part of the pilot car is occupied by machinery. On the extreme front are laid splice bars and bolts within easy reach of the strappers or bolters, while the rear part is used for tool boxes, track tools, and short rails. Seven men are employed on the train, as follows: 4 men behind the engine loading ties into one tramway, 2 men loading rails into the other tramway, and 1 man at the stationary engine.

These machines were used on the Northern Pacific Ry. in 1890, where the work was obstructed by bridges, etc., so that they could not be worked continuously forward, and they averaged from 4,000 to 5,000 ft. as a half-day's work, while a rate of 9,000 ft. in six hours was frequently made with 28 to 32 men with the train. They have also been used on a number of other roads, mainly in the far West, but below is given a report of operations on a road in Illinois:

The Roberts steam tracklaying machine was used in 1894 on the Chicago, Paducah & Memphis Ry. between St. Elmo and Mount Vernon, Ill. Mr. F. P. Read, Chief Engineer, stated that the average speed was:

TABLE NO. 20.—TRACKLAYING GANG WITH ROBERTS' MACHINE; C., P. & M. RY.

36 Men With the Train,	44 Men Behind the Train,
3 foremen,	4 men distributing splices and spikes,
1 engineman on machine,	4 back strappers,
4 men loading ties on trams,	16 back spikers,
2 men loading rails on trams,	8 back nippers,
7 men placing rails,	1 oiler,
8 men placing ties,	5 lining track,
4 head spikers,	6 spacing ties.
3 head nippers,	
3 head strappers,	
1 tie liner.	

two miles per day, and the record-breaking time was one mile in 2 hrs. 50 mins. The rails weigh 60 lbs. per yd., and there are 2,815 ties per mile. The train was made up with the pioneer car (having a small engine supplied with steam from the locomotive) and five cars of rails in front of the locomotive, and twelve cars of ties behind the locomotive. These sup-

plies were for half a day's tracklaying. There were 80 men required to lay and finish two miles of track per day. The gang with the train operated the machine, took all material from the cars, put it in place, and full tied, half-bolted, and quarter spiked the track. The gang following the train completed the work. The distribution is given in Table No. 20.

Ballasting.

For a new line, the ties are laid upon the subgrade, and when the rails have been laid, the ties are tamped with earth and the track is lined and surfaced to make it safe for the ballast train to run over it without injuring the rails or splices. In some cases, however, the track is jacked and blocked up above the subgrade before the ballast is distributed. The ballast is hauled upon the track in trains of gondola or flat cars, from which it is shoveled or plowed, but the ballast should not be distributed until the banks are properly completed and the roadbed is finished to the standard cross section, so that the ballasting material will not get mixed with the earth and clay of the roadbed. In reballasting, if the original material is very old and dirty it should be removed, as it will be so choked up as to prevent proper drainage. Old broken stone ballast may be shoveled out and then handled and put back with forks, being thus freed from dirt and small matter. On roads having a good supply of gravel available, it will be found economical to have ballast trains at work to keep the track well ballasted, as this will much reduce the work in wet weather, or in winter when the frost is in the ground. On the other hand, it must be recognized that ballast is usually somewhat expensive and should not be used for filling in sags, or wasted down the sides of banks. Slag, however, being usually very cheap, may be used for filling and for ballast.

When the ballast is distributed, the track is raised by jacks (both sides at once) for a distance of about 100 ft., and lined by bars. The ballast is then shoveled and tamped under the ties. Two lifts are usually made, and the inclined parts approaching the raised portion must be made solid enough to prevent injury to the rails and joints by passing trains. The grade stakes should be sufficiently close together to allow of the use of a 16-ft. straight-edge, as the ties are put up to grade better in this way than when the stakes are further apart, and intermediate ties are sighted in.

If much work is to be done, it is economical to use a steam shovel for loading the cars and a plow for unloading them on the track. Hand shoveling from gondolas is expensive work, unless for small jobs or where small quantities have to be thrown off at various points. Small side-dump cars are occasionally used, but the most general practice is to have trains of flat cars, with low sides of loose boards supported by short stakes in the stake pockets, while iron aprons between the cars serve to keep the ballast off the rails. On the rear car is a heavily weighted plow, guided by the side stakes or by a longitudinal timber along the middle of the floor of each car. To the nose of this car is attached a steel cable extending over the cars to the locomotive, and being led through pulley blocks on chains attached to the sides of the cars if the unloading is done on a curve. When the train reaches the place where the ballast is to be unloaded, the train is stopped, the car brakes are set, and the locomotive is then uncoupled and run slowly ahead, hauling the plow along the cars and

plowing the material to one or both sides, according to whether a side or a center plow is used. One of the best plows is the Barnhart plow of the Marion Steam Shovel Co., which has a front and rear guide hinged to the plow to keep it steadily in the center of the car, the cable being attached by a hinged joint to the front guide. With loose gravel, the engine can be run at about 4 to 6 miles per hour. When the plow has been drawn the length of the train, the cable is unhooked and thrown to the side of the track for the use of the next train. In filling and ballasting on the four-track work of the New York, New Haven & Hartford Ry., when the cable had been hauled the length of the train it was thrown to the side of the track and its end was hitched to a stand or derrick resembling a mail crane. The next train, running slowly by, picked up the cable, placing the end on the first car, while the stand held it in position over the cars until laid the full length of the train. The cable was thus handled by one man, while in ordinary practice it takes several men a considerable time to place the heavy steel cable on the ballast cars.

When distributing ballast in this way, the entire train load must be plowed off at one place. A very convenient arrangement, however, by which the distribution can be regulated, is by the use of the Lidgerwood "rapid unloader," which consists simply of a winding engine mounted on a car between the engine and the first ballast car, steam being supplied from the locomotive or from a boiler on the car. With a train made up in this way all the material may be dumped in one place, or any desired quantity can be unloaded and distributed by the locomotive moving the train along while the plow is being hauled along the train.

An ordinary ballast car, 33 ft. long and 9 ft. wide, with side boards 10 ins. high, can be loaded with 15 to 20 cu. yds. of ballast.

The ballast being thus distributed at the sides of the track has to be shoveled into place between the rails, but such rehandling is obviated by the use of a train of the Rodgers ballast cars. These are hopper-bottom cars, 34 ft. long, of 18 to 22 cu. yds. (or 50,000 to 60,000 lbs.) capacity. The hopper opening is narrow, and so arranged as to deliver the ballast in the middle of the track and not pour it over the rails. The hopper doors are opened to any desired width by a man walking along the cars, the quantity delivered per yard of track being governed by the speed of the train and the width of hopper openings. At the rear of the train is the plow or spreader car, which is a flat car fitted with a double mold board steel plow, with flangers fitted to the edges. This plow can be raised or lowered by a screw and rides on the rails when in use. The ballast delivered in a ridge between the rails is plowed down between the ties and out over the rails (the rails being cleared by the flangers) so that it lies between and outside the rails ready for the tamping, as soon as the track is raised by the jacks. The train can be run at the rate of 3 to 5 miles per hour while delivering the ballast. These cars are built by the Rodgers Ballast Car Co., of Chicago. Other forms of ballast plows and spreaders are used, and where ballast is plowed off the train for double or four-track work, the rear car is sometimes fitted with an inclined spreader which projects from the side of the car and spreads the dumped material for a width of about 15 ft. from the ballast train track, either on one or both sides, according as to whether a side or center plow is used.

The Pratt ballast dump cars used on the New York, New Haven & Hartford Ry., are of 25 cu. yds. capacity, being rated at 60,000 lbs. carrying capacity. They are 28 ft. long inside, are carried on ordinary freight car trucks, and weigh 25,000 to 26,000 lbs. empty. The sides are made in two parts, divided horizontally. When the train stops, the upper half of the side of the car is swung down, and half the load dumped. The train then moves on a train length and the lower half of the side is swung up, dumping the rest of the load.

In building the additional tracks for the four-tracking of the New York, New Haven & Hartford Ry., between New York and New Haven, a temporary track of old material was first laid on the subgrade, and the ballast then hauled in and the temporary track raised by jacks to the proper grade. After this the old track was replaced by the material for the permanent track, which was thoroughly tamped, surfaced and lined. The ballast was of broken stone, carried on low, drop sideboard cars, each holding 10 cu. yds., and the unloading was done by hand. From this first new track the ballast for the two adjoining tracks was then unloaded, and was leveled off to the bottom of the ties by means of a leveler or spreader. This consisted of a heavily-loaded flat car fitted with wings 20 ft. long, these wings having plate iron scrapers, adjusted by means of two ratchet jacks. When not in use the wings are folded against the side of the car, and the car can then be hauled over the road in any freight train. On the bed thus prepared the new tracks were laid, and were ready for slow-running trains as soon as the spikes were driven, there being no danger of bending the rails. It will readily be seen how the ballast may be distributed and leveled for any number of parallel tracks after the first track has been laid.

When gravel ballast is to be put in on a track ballasted with earth, the earth between the ties should be dug out and placed at the side of the roadbed. A train load of gravel is then dumped, giving about 15 cu. yds. per car length, and this is then packed down to make room for another load, filling it in level with the tops of the ties. The track is then raised by jacks, and the gravel shoveled under the ties, after which another load of ballast is deposited. The track is then again raised, the ties are spaced properly, the final tamping done, the track lined and surfaced, and the ballast finally dressed to the required cross section.

CHAPTER 16.—DRAINAGE AND DITCHING.

The question of the drainage of the land traversed by a railway is an important one, but comes more properly under the head of construction or engineering work than of track work or maintenance; and it is not intended to consider this question here, but rather to consider the drainage of the railway as constructed. There are, however, some general points which it may be well to briefly mention. The necessity of providing ample waterway at all bridges and culverts is insisted upon in nearly every book on railway work, but it is not always observed as closely as it should be. In the maintenance work, therefore, the engineer, superintendent, roadmaster and section foreman should have in mind what culverts or

waterways are occasionally found to be of insufficient capacity. Until increased capacity can be obtained they must take care that the opening is free from drift and obstructions, that no fencing is placed across it and that the sides of the stream or the slopes of the embankment, etc., are protected from wash. This protection may be in the shape of rip-rap, brush, rough cribbing of trees and logs, or trees laid on the slope with the trunks pointing up stream, and the branches weighted down in the water.

It is now generally recognized that as every opening on the railway is to a certain extent a source of danger, these openings should be reduced to a minimum, and therefore the common open culverts are on many roads being rapidly replaced by culverts of iron or vitrified clay pipe (one or more lines of pipe according to the waterway required), stone box drains, or masonry arches, with a solid bank filled in over them. Such culverts, of proper capacity, and with ends properly protected from scour, are, of course, much less liable to washouts or undermining than pile culverts. Rectangular or box culverts of masonry should have a waterway not less than $2\frac{1}{2} \times 3$ ft. The abutment walls should be at least 2 ft. thick (or two-thirds the length), resting on a paving of 10-in. stone, set on edge, the ends of this paving being protected by curbing and broken stone aprons. The covering should be of stone 12 ins. thick, with 10 ins. of bearing on each abutment wall.

Portable culverts of steel plate construction have been proposed, and have been used to a limited extent for highway culverts. They are of trapezoidal section, the sides being strengthened by angle irons, and the ends having steel plate portals and wing walls. It is claimed that they can be built at the shop and sent out ready to be placed on a prepared concrete foundation. The steel is painted with a non-corrosive protective paint. These culverts are being introduced by Mr. W. A. Nichols, of Philadelphia.

The method of draining the water from the track and from the land on each side will depend upon the character of the soil and the amount of water to be dealt with. In some exceptionally bad cases, special treatment is necessary to prevent slides, particularly where quicksand, gumbo, or clay overlying rock are encountered. In Europe, heavy permanent works of masonry are sometimes undertaken for dealing with slides, or for the drainage of wet or unstable material traversed by a railway. Valuable articles on this class of work will be found in "Engineering News," New York, Sept. 22, 29; Oct. 6, 13, 1877; in the "Journal of the Association of Engineering Societies," 1894; and in the "Annales des Ponts et Chaussees," October, 1893.

In all cuts there should be a good ditch on each side of the roadbed, and the distance of the ditch from the rails should vary with the material of the cut, for in rock or hard material the water may be safely carried closer to the ballast than in wet clay or earth, when the water will seep into and tend to saturate the roadbed. From this it follows that cuts in soft material should be wider at subgrade than those in hard material, although in practice the cuts are often made too narrow to allow of proper ditches and expense is incurred in subsequent widening or in constant maintenance and in cleaning ditches. The slopes, also, are often left too steep, thus preventing the construction of proper ditches, and increasing the liability of slides in wet material, or causing a constant falling of material into the ditches. Some of the wet gumbo cuts on the Canadian

Pacific Ry. have had to be cleaned out and deepened with a steam shovel and then two rows of piles, 8 ft. apart, driven on each side of the track. Sills laid under the roadbed kept the inner rows from moving, and inclined braces were put in between the inner and outer rows. The mud was dug out and coarse gravel filled in around and behind the piling through which gravel the water drained to the track ditches. In a case mentioned by Mr. H. W. Reed, formerly of the Savannah, Florida & Western Ry., a clay cut, about 20 ft. deep and 300 ft. long, at a point that was formerly the head of a small natural drain, gave a great deal of trouble during wet weather by the slope on one side sloughing off and falling in, causing the track to rise suddenly, sometimes as much as 3 ft. in one night. Tons of this earth were removed as it fell in, until the earth from that side of the cut had been removed some 70 ft. from and to a level with the track, still the difficulty was not overcome. Open ditches were powerless to reduce the saturation of the semi-liquid mass. Tile drainage was proposed, and a drain 6 ins. diameter was carefully laid parallel with the track, 4 ft. from the ties and 3½ ft. below the level of the track, on the side where the sloughing occurred. An open ditch was dug on the opposite side of the track. The first wet spell after this the track again began to rise and had to be cut down, and the open ditch reopened repeatedly. The tile drain was broken up by the movement of the earth, and parts of it found to have passed entirely under the track into the ditch on the opposite side. Soundings indicated that the soft mass extended about 30 ft. below the track, and was apparently slipping over a strata of hard clay with an inclination toward the track. A row of round sheet piling was driven about 8 ft. from the track and 20 ft. deep. It was intended to brace this piling by means of struts under the track and against the opposite wall of the cut, which stood immovable; but a season of heavy rain coming on prevented the execution of this part of the work. It was expected that the earth would force the piles toward the track, and that the old difficulty would again reappear. Such was not the case, however; for, notwithstanding months of heavy rains, the piling and track stood unmoved, and the problem was solved.

Round or sheet piling is also sometimes necessary in the slopes or at the toes of cuts. In soft cuts deeply gullied by rain, cribs of old ties are sometimes used, but are very unsightly and generally of only temporary value. If such cribbing is used, the pile of ties should be higher at the track end, the ties sloping back to the bank, so as to afford greater resistance to displacement of the cribbing, while the edge forms a convenient platform from which to shovel the sliding clay into the cars until the angle of repose has been reached. It has also been found in cuts through clay with an overlying stratum of earth, that if the material is excavated to a vertical face at about the middle of where the ordinary slope would be, when the face sloughs off the earth will cover the clay and protect it from the weather. Where slides occur or are liable to occur, and it is difficult to keep the ditches clean, some additional means of drainage should be provided. Wooden box drains, pole drains, or trenches filled with saplings may be used in wet cuts. If a slide occurs in winter or in bad weather, ditching it out will often keep it sliding or make it worse, and in such cases, as long as the material does not encroach on the track, it is often best to leave it and cut cross drains through the ballast to carry the

water to the ditch on the other side of the track. If the proper width for slopes and ordinary ditches cannot be obtained, as in cuts through valuable property, masonry retaining walls may be built near the track, and the slopes commenced from the tops of these walls.

One of the great troubles with heavy rainfalls, is the gullying out of the slopes and the breaking down of the corners of cuts and banks, for which reason it is a good plan to round off the top and bottom corners, as in the section shown in Fig. 200. Mr. D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry., has advocated this course, together with the paving of ditches and the sodding of slopes. The washing of slopes, especially in sidehill cuts, may be checked by cutting a berme or surface ditch at some little distance from the top, so as to intercept the surface drainage. The ditch should be at least 3 ft. from the cut, with the earth thrown out on the side next to the cut. It may be about 18 to 24 ins. deep, 12 ins. wide at the bottom, the size varying with the amount of water to be dealt with. The ends should be curved out, or led into the berme ditch of the adjacent bank, so that the water will not wash the face of the bank. If the earth is very soft or porous the ditch may be

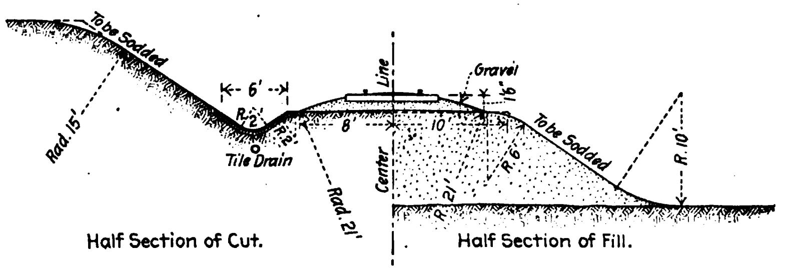


Fig. 200.—Cutting and Embankment with Rounded Corners.

lined with plank or even concrete. Another method is to have blind drains cut diagonally along the slope and filled with bundles of brush or saplings, broken stone, or semicircular tile. In still other cases, drains are constructed, consisting of trenches about 2 ft. wide and 2 ft. to 3 ft. deep, cut straight up the slope and filled with broken stone. The distance between these trenches depends upon the amount of water and the character of the material. Where springs break through the slope, drain pipes may be inserted, and a gutter or an apron of stone rip-rapping laid from the outlet down to the track ditch. In such cases, subdrainage may be required.

A sodded slope will prevent washing, and largely prevent sliding, except with very wet material and a continuous heavy rainfall. In England, great care is taken with the sodding and grassing of slopes of banks and cuts. The cost of sodding may be about 7 cts. per sq. yd. On the Cape Cod Division of the New York, New Haven & Hartford Ry. (Old Colony Line), the slopes of sandy cuts and banks are protected somewhat from rain and wind by encouraging beach grass to grow on them, but as this will not grow so well on the slopes of cuts, old ties are sometimes laid on the latter. The roadbed of the Southern Pacific Ry. on the south side of the San Gregorio Pass (in southeastern California) was originally com-

posed of sand, and sometimes suffered during high winds. This was checked by embedding dry brush in the embankment, with tops and branches outward. Where the Siberian Railway crosses sandy plains, the roadbed is protected by rows of low scrub bushes, which serve partly to prevent the sand from being blown away by the wind, and partly to consolidate the soil by their roots.

Banks may be drained by berme ditches not less than 3 ft. from the toe of the slope, and the men should never be allowed to take material from the intermediate berme or level for filling the bank or raising sags. The bottom of the ditch should slope slightly away from the bank. If there are springs underlying the bank, tile drains may be laid from the springs to the side ditches, or the earth may be dug out, broken stone and rock filled in, and rock filled trenches made from the hole to the ditches. Special care should be taken with the drainage on sidehill work to keep the bank itself and the ground upon which it rests well drained. In some cases benching and extra side filling or dwarf retaining walls are required to keep such a track in line. Trackmen should never be allowed to use the material from the top of the bank for ballast.

Swampy ground requires special treatment of the roadbed, and the Canadian Pacific Ry. has built some sawdust banks across swamps where gravel would break through the surface crust. The slopes are covered with earth to protect the material from fire. The Minneapolis, St. Paul & Sault Ste. Marie Ry. crosses a number of swamps in Wisconsin, many of which show soundings of 15 to 30 ft. Upon these is made a roadbed about 2½ ft. high from ditches cut at a distance of 15 to 30 ft. from the foot of the slopes. The material is mostly peat, which, when dried out, makes a very light bank. The track was laid on small poles (3 to 4 ins. diameter), three under each end of the ties, and only enough ballast was used to bring the track to a good surface. These swamps gave some trouble from the track crawling under the heavy consolidation engines (120,000 lbs. on the driving wheels). In some places ties 10 and 12 ft. long were used, and in some instances angle bars were bolted to the middle of the rail and spiked to two ties. A 12-in. foundation of logs, about 6 ins. diameter, is sometimes built across swamps, being covered with bushes and a little ballast. Ditches are usually dispensed with in such construction.

Suburban and Tile Drains.

Subdrainage is frequently necessary where the roadbed is in damp or wet ground, and where trouble is caused by heaving. Tiles and broken stone are used for this purpose, the tile being the better. The tile drains are usually laid under the ditches on one or both sides of the track, and 2½ to 3 ft. from bottom of ditch to bottom of tile is generally sufficient, but in any case the tile should be below the frost line to protect the tile from heaving or breakage. The ends of the drains discharge into culverts or waterways. Good track cannot be maintained in wet and soft places without subdrainage, and there are many spots in cuts and under banks (especially in sidehill work) where water seeps through badly, and where nothing but subdrainage will afford substantial relief. In wet cuts the tile may be laid in diagonal lines at a depth of about 3 ft., and 6 ft. to 20 ft. apart. A track with tile drainage is shown in Fig. 6.

The best and cheapest material for subdrains is the common porous

red clay drainage tile, without collars, though glazed tiles with open joints are used in some cases. The smooth surface of the tile gives a rapid flow for the water and consequent reduction of saturation of the roadbed. It should be not less than 5 ins. diameter, and of ample size to carry off all the water freely, as there is little difference in the cost of laying 5-in. or 10-in. tile. Great care should be taken to lay it properly, getting tight joints and uniform grade with all the fall the outlet will allow (the grade to be not less than 3 ins. to 100 ft. in any case). It should be covered with slough grass, if possible; although hay or straw are better than nothing. The trench is then filled with cinders, gravel or other porous material, if any can be had. Otherwise stiff joint clay may be used, but not sand or loam, as they will work into the pipe. The trench, however, may be filled with such material. In laying in quicksand or mud it may be necessary to use a plank bottom or trough covering as fast as laid, to prevent displacement. When putting in tile on only one side of track, it should be laid on the upper or higher side. Where a spring underlies the roadbed in a cut, tile cross-drains may be laid at intervals, sloping slightly towards the sides and connected at each end with the tile drains under the ditches. The outlets of all drains should be looked after and kept free, especially in winter, as springs may keep water running in cold weather. Some loose stone should be laid up around the ends to keep out small animals, or wire netting answers admirably for this. Both ends of the drain should be kept open and free to allow circulation of air through the drain. The cost of laying tile will vary from 25 cts. to 60 cts. per rod, according to material, or even more in quicksand cuts. In general the drains, if of any extent, are laid by men experienced in this particular work, and not by the ordinary section gangs, as the former can usually do the work quicker and cheaper. In laying the drains, the tiles or pipes are kept in line during tamping by stringing them upon a pole or rod about the diameter of the pipe, this being left in place until a length of backfilling and tamping is done, when it is pulled ahead for another set of pipe, its heel remaining in the pipe already laid as a guide.

Ditches.

The proper construction of roadbed ditches has already been referred to, and on all roads in districts where much rain falls, one of the important items of track work is that of keeping the ditches clear and properly graded, for well-drained earth may make a better roadbed than badly-drained gravel. Earth from the slopes and ballast from the roadbed fall into the ditches and gradually form obstructions which choke the waterway, while in soft material the ditches will gradually close up. In the spring, therefore, as soon as the frost is out of the ground, every section foreman must have his ditches properly cleaned and improved; and in the autumn he must again overhaul them, clearing out leaves and rubbish, and putting them in condition for winter. In doing this work, attention should be paid to getting even grades, proper dimensions for an ample waterway, and a uniform direction, cutting away stumps, boulders or rock edges which interfere with the course of the ditch, as twists and bends around small obstructions are liable to catch floating objects and to cause a choking of the ditch. Attention must also be paid to getting a good discharge for the ditch at the end of the cut, so that the water will

not wash the adjacent bank. The ditch should be commenced at the lower end of its grade, so that the work will drain itself as it progresses. Sections of ditches are shown in the chapter on Roadbed Cross Sections, Part I. On curves it may sometimes be necessary to carry the water along the inside of the curve to prevent washing of the roadbed or ballast, and for this purpose the outside ditch is dammed at intervals and an open box drain of wood laid across the roadbed to carry the water to the inside ditch. When ditching in yards, the foreman should arrange with the yardmaster and do the work at a time when the sidetrack next the ditch can be kept clear of cars.

Ditching is usually done by hand, the earth being shoveled into a push car, which is then run to the end of the cut and dumped over the bank, a flagman being sent out to protect the car. The earth should never be thrown upon the slope of the cut, or on the top of a shallow cut, as it will only wash or fall in again. If the earth can be loaded, hauled and dumped by a car, as above described, without interfering with trains, this is the best way to work. In many cases, however, wheelbarrows are more convenient, a wheeling plank being laid on the inside of the near rail, care being taken that the planks are not so thick or warped as to interfere with the flanges of car wheels. Wheelbarrows having grooved wheels to run on the rail head are sometimes used, and are claimed to be specially useful where the traffic is heavy and two flagmen would have to be sent out if a car was used. In wheelbarrow work, the foreman should put one of his best men in front and a second best man at the rear of the wheeling gang, so as to get out to the dump and back again as quickly as possible. If the work is extensive, a work train and extra gang may be assigned to it, the earth being loaded on flat cars and hauled to any convenient place for deposit. Whether it is best to employ trains, push cars or wheelbarrows, will depend upon local conditions, the length of cut, number of trains during working hours, extent of work to be done, number of men in the gang, etc.

Ditching Machines.

On railways running through low-lying, damp and swampy districts, and having the grade line but little above the normal surface of the country, the question of drainage is a very important one in the maintenance-of-way work, and a considerable amount of money and labor must be expended in making and maintaining ditches in order to keep the roadbed and bank in proper condition. This is especially the case where the ballast is poor, and where the natural soil is used for ballast. A combination of the above conditions exists on a large mileage of railways in the Southwest, and there is consequently a good field for the application of ditching machines in order to expedite the work and reduce the cost for labor. A very handy and labor-saving device is a ditching car, which consists of a flat car with a derrick from which is slung a scoop of about 1¼ cu. yds. capacity. The scoop is guided by chains, and the car is run slowly by a locomotive. The car may also be fitted with mold boards or scrapers for dressing the ballast to proper contour. The ditching machine made by Pettibone, Mulliken & Co., of Chicago, consists of a heavy framing mounted on a flat car and supporting two derricks at the side (or two derricks on each side for single track work). The derrick chains support

the front and back bails of a ditching scoop or scraper, while a chain from a horizontal bail in front of the scoop is fastened to the frame at the front of the car. This chain does the pulling, the others regulate the depth of cut, and the derrick regulates the distance from roadbed to ditch. There is a man at the winch of each derrick, and the crew consists of 8 men in all, the crew being sheltered by a roof over the framing. The machine will work in dry cuts when they have been plowed, but it works best in wet weather, when the material is soft. The car should be strong and well braced, and have the spring hangers duplicated or reinforced, as it is subjected to severe strains. There should be no slack between the engine and car, so as to prevent jerking. Cars of this kind are used on a number of railways, and such a car can be rigged up on any division, and fitted with a ditching plow, a ditching scraper, or a mold board for dressing ballast slopes, as noted under "Clearing Right of Way," in Chapter 17.

A very completely equipped car for heavy work of this kind is used on the St. Louis Southwestern Ry., having been built by the American Steel Foundry Co., of St. Louis, to the designs of Mr. W. B. Doddridge, General Manager of the Missouri Pacific Ry. The car is 46 ft. long, having plate girder side-sills connected by angle iron transverse bracing. The end sills are heavy steel castings, and have extended curved ends to serve as attachments for the draft chains which pull the outer end of the scraper and the beam of the ditching scoop. At the middle of the car is a steel derrick post, 9 ft. high, seated in a frame below the floor and carrying a crane arm or jib having a reach of 14 ft. The crane can be turned through a complete circle. The car is carried on two four-wheel trucks, having diamond frames and cast steel bolsters. All operations of the handling of the various parts are effected by means of compressed air. The air supply is stored in three cylindrical reservoirs, 22 ins. diameter and 10 ft. long, at a pressure of 80 lbs. per sq. in., and is supplied by the air-brake pump of the locomotive of the work train. These reservoirs are placed underneath the car, and there are also placed the following operating cylinders: One cylinder, 12 ins. diameter and 14 ft. 7 ins. long, for the derrick hoist; one cylinder, 12 ins. diameter and 9 ft. 5 ins. long, for swinging the derrick, the piston rod having a rack attachment for swinging the mast through a complete circle; four cylinders, 8 ins. diameter and 5 ft. 4½ ins. long, for the side guides. All the pistons are cushioned by air, and the cylinders take air pressure from either end. The various pipes are brought together to a "switchboard," mounted on the car, and all movements are controlled by cocks operated by a man standing at this switchboard.

The main equipment of the car includes the following: (1) A solid cast steel plow, weighing 2,500 lbs., which cuts a furrow 20 ins. deep and 36 ins. wide; (2) A triangular shaped scraper for cutting material for the embankment; (3) A mold board for dressing the roadbed to the standard section; (4) A ditching scoop of 3 cu. yds. capacity.

The general course of operation is as follows: The plow is first used to cut one or two furrows, as may be necessary, to lower the ditch to the proper depth and furnish sufficient dirt to fill out the embankment to the standard section. The necessary beams, guides, etc., are so arranged that the plow is entirely under the control of the man handling the air; it can be set at any distance from the track that is desired, raised or lowered, or swung in or out to avoid obstructions too large to plow up. The nose of the plow

is braced by a heavy bar attached to the side sill. The scraper is then used to bring the dirt from the ditch up toward the track. If the ditch is in a small cut, however, with banks not exceeding 5 or 6 ft. high, and the dirt is not required on the fill, the scraper can be reversed so as to remove the dirt from the ditch, throw it outside and form a bank of even and regular surface. The mold board or shoulder former is then used to dress up and finish the embankment. This tool extends from the ends of the ties at an angle of 30° with the car body, for a distance of 14 ft. As it is braced and held rigid with the car, the embankment is shaved perfectly smooth and exactly to template, no matter what is the elevation of the track. The template is bolted to the lower edge of the mold board. Where the scraper has brought up too much dirt, the mold board removes it, carrying a sufficient quantity before it to fill up the low places where not enough dirt has been left. The tool can be readily adjusted as required, and can

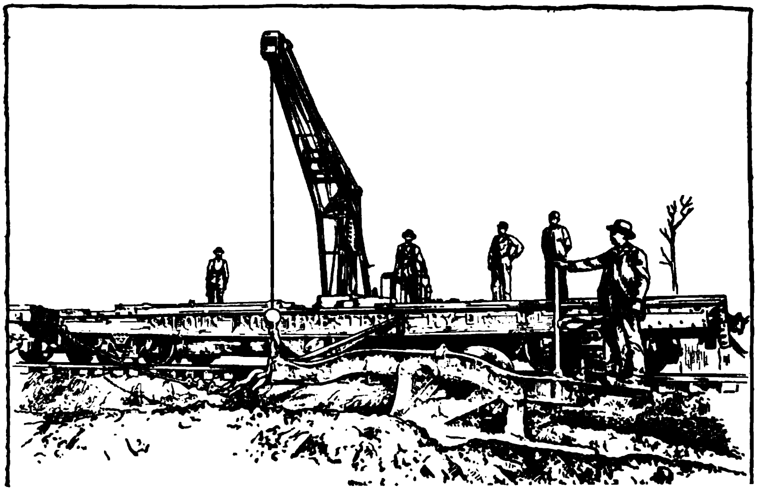


Fig. 201.—The Doddridge Ditching Machine.

be raised easily to allow it to pass cattle guards, bridges, and road crossings. The track is then ready for ballasting.

The ditching scoop or excavator is an important part of the equipment, when ditching in deep cuts or preparing to lower track. It is attached to the car in the same way as the other tools, and is worked somewhat in the manner of a drag scraper or the dipper of a steam shovel. The dirt is scooped up and the car run out on the embankment, where it is dumped. The whole operation is handled by air, the derrick raising and lowering the scoop and tipping it to dump the load. With this tool, cuts can be excavated to any depth desired, from the ends of the ties out to a distance of 14 ft. The scraper and the scoop are attached by chains to a heavy steel beam, pivoted to the extension of the frame below the sills, and held in position by chains from the side and a rod from the end sill. The mold board is hauled directly by a chain attached to the end sill.

It has been found most convenient to work an entire day on one side of the track. When not delayed too much by passing trains there is no trou-

ble in ditching and dressing up the embankments on one side of the track for a distance of 1½ to 2 miles per day, leaving a neat, well-drained and well-trimmed roadbed. The force required to operate the outfit consists of the conductor of the work train (who acts as the foreman of the work), two brakemen, one man to handle the air, and two laborers to make and change the various chain hitches. The entire cost of such labor is $18.30 per day. The locomotive propelling the machine moves at a rate of about four miles per hour, hence it is stated that the amount of work done in a day, at a total cost of about $30, would cost $500 to $1,000 if done by laborers. Besides this the embankment is left perfectly true to the standard section and in better shape than would be possible if the work was done by hand. This machine was illustrated in "Engineering News," May 7, 1896, and its work in plowing is shown in Fig. 201.

CHAPTER 17.—TRACK WORK FOR MAINTENANCE.

The maintenance work on track includes the various kinds and details of work required to keep the track in safe and proper condition for traffic. It varies, of course, with the climatic conditions, and also varies with the character of the track and the amount of traffic, being specially hard under conditions of a light track carrying a heavy traffic. If the road has been carefully located and built, with easy curves, well arranged grades, and a good track, then the maintenance-of-way department has an excellent chance to maintain a practically perfect track at small expense. If, on the other hand, the road has been laid out and built hurriedly and carelessly, with a main view to cheapness, and if it has narrow cuts and banks, curves used recklessly and badly put in, and long steep grades used unnecessarily, then there will be trouble with the trains and continual trouble to keep the track in reasonably fair condition. Eventually, perhaps, railway companies will recognize more generally the principles of economics, and will build, rebuild and maintain their lines accordingly. Then they will use rails of ample weight and strength for the traffic, will take means to prolong the life of ties, and so reduce the frequency of renewals, and will purchase material on its merits rather than its price. With such a system a great reduction may be expected in the labor and expense of maintenance. It is not sufficiently recognized by executive officers that the increased cost of maintenance with old rails and ties, worn-out fastenings and poor ballast often exceeds the interest on the investment for new material.

From 60 to 75% of the damage and wear to track is caused by the engines or engine mileage, and the balance by the trains, with their far greater number of wheels. This is due to the greater wheel loads, the closer concentration of these loads, and the destructive effects resulting from bad counterbalancing, slipping of driving wheels, use of sand, etc., to say nothing of the wear of frogs and switches by badly worn driving wheel tires. The car is merely a passive rolling weight, and while flat spots in car wheels or the general use of very heavy car loads may aggravate the destructive effect of the car wheels, it is not probable that the proportion of damage due to the train would approximate that due to the engine wheels. Freight trains are usually more severe upon the track than are passenger trains, as the engines of the former are more liable to be pulling hard, while the cars

of passenger trains have lighter wheel loads and easier riding trucks, owing to the better arrangement of the springs. Heavy sleeping cars weigh from 90,000 to 112,000 lbs., or 7,500 to 9,333 lbs. per wheel. Freight cars weigh from 24,000 to 36,000 lbs. empty, or 64,000 to 120,000 lbs. loaded; giving loads of 3,000 to 15,000 lbs. per wheel. The latter is very exceptional, with cars of 70,000 lbs. capacity. Freight locomotives have driving wheel loads of 12,500 to 20,000 lbs., and have from two to four such wheel loads imposed on a wheelbase of 12 to 20 ft. A fully loaded 60,000-lb. car, with a total weight of 88,000 lbs., has eight wheel loads of 11,000 lbs. on a wheelbase of about 25 ft.; while a ten-wheel freight engine may have six driving wheel loads of 18,000 lbs. on a wheelbase of 12 ft. Besides this the locomotive loads are standard, while the car loads are fluctuating, the maximum (as given above) occurring comparatively rarely in regular freight service.

The work should be done systematically, and not at scattered points along the sections. The amount of time and labor which may properly be expended on the appearance of the track depends largely upon the financial conditions. Hand dressed ballast, turfed slopes, etc., can only be expected on comparatively wealthy roads, but neatness of work should be seen on every road, as neatness involves no expense, but is rather conducive to economy. The maintenance of way is an endless work, the basis of which is surfacing, and its monotony is varied occasionally by more or less extensive extra work in the way of relaying track, reballasting, or building additional tracks. It may seem trite and unnecessary to remark upon the necessity of good work, but how often are seen (even on leading roads) rail joints with bolts missing, ties misplaced, old shims left in place, etc., and work done to look well. It is not always possible for the roadmaster or engineer to get what he considers to be the best materials, and he must then do the best with what he has. Thus many a man considers tie-plates to be more effective than rail braces in maintaining gage on curves, but if his road will not supply the plates he must use the braces to the best advantage. He may also have bad sags in the grade line, causing trouble with freight train couplers, but if he is unable to get the material necessary for filling in he must do his best to ease off his track at the ends of the sag to give a more even approach. In case of any important work being undertaken the traffic department should be notified.

In the general work on the section the roadbed slopes and ditches must be maintained according to the standard plans, and if the original construction does not conform to these standards, then all subsequent work should be done with a view to attaining them. In some cases the standard dimensions (as for ditches, etc.,) may not be sufficient under local conditions, and in such cases they should be exceeded so as to give the required capacity. All material taken out in widening cuts or ditching should be hauled away and used for widening banks, being shoveled clear of the ties and below the level of the bottom of the ballast so as not to interfere with the drainage. The ballast must be kept free from weeds and in proper slope, being promptly restored to shape when broken down by stock or trespassers. Center and grade stakes should be tested and reset every three or four years, and on sharp curves and transition curves the center stakes should be tested once a year.

One of the greatest causes of bad track, bad riding track and damage

to rails, is the low rail joint. When a joint has once become low it rapidly gets worse unless promptly attended to. If the ballast under such a joint is dirty or bad it should be cleared away and good ballast put in and well tamped. In many cases rails are badly damaged and bent by hauling over them "dead" locomotives (not using steam) with the side rods taken off, the counterbalances then having a very destructive effect on the track. Rails, frogs and switches are also subject to injury from engines with badly worn tires. All such cases of damage should be promptly reported, and the transportation department should be requested to adopt strict rules as to the speed at which "dead" engines may be hauled. When a broken rail is found it should be at once spiked, and, if possible, a pair of splice bars placed at the break and bolted or spiked. Trains should be flagged until the broken rail has been securely spiked and spliced or a new rail put in. An investigation should be made and a report prepared in each case of rail fracture. Switches should be frequently examined, to see that the switch rails have the proper throw or travel, the switch rods adjusted to give the proper position of the rails at each end of the travel, connecting pins in place and secured, and slide plates greased and free from dirt, stones or other obstructions. Spring-rail frogs must also be looked after and kept free from obstructions. Particular attention must be paid to the telegraph lines. If found broken or on the ground, crossed or obstructed, they must be at once repaired in a temporary manner and due notice given. Should repairs be impracticable, notice must be sent at once to the nearest telegraph office.

In tunnels and on bridges the work of maintenance is somewhat different from that on the roadbed. Refuges should always be provided at intervals in tunnels and on long trestles. If there is heavy traffic through the tunnel, the maintenance work is specially difficult, so that the men cannot work to advantage, as they have to be continually getting on and off the track and seeing that their bars, tools, etc., are clear of the rails. Foremen should be particularly careful in such cases, and should put out "slow" signals if they are doing any heavy work. Portable electric lights, oil lamps or torches, or Wells lights may be used, the latter being of special advantage. The work of renewing ties, rails, etc., under such conditions, is not only difficult and dangerous, but expensive, and it will be economy to make a somewhat large expenditure upon an exceptionally heavy and substantial track in such cases, so as to reduce the maintenance work. When the track is found out of line or surface at bridges and trestles, the roadmaster should make an investigation and notify the officers of the bridge department. Temporary repairs should then be made, if necessary, and "slow" signals put up until the track has been inspected and rectified.

Hand cars must be run with caution, and slowly in foggy weather and through towns or near grade crossings. They should not be used in foggy weather unless the place where the men are to work is more than a mile distant. They must not be run within 20 minutes of the time of a regular train, nor in the wrong direction on double track. It is best to start directly after a train (care being exercised as to trains following closely), and on single track to then run the car at full speed to such a point as a train in the opposite direction may be expected. If there are curves and cuts on the line, obstructing the view of the track, a man may be sent ahead as

far as he can see the car and also see further along the line. If he signals that there is no train approaching, the car can be run up to him at full speed, but if he signals that a train is approaching there is ample time to take the car carefully off the track. If the car is left near a road crossing while the men are at work, the wheels should be locked, but it is best not to leave it in such a place. Rails should not be carried on the hand car except in cases of emergency.

Before disturbing the track for rail renewals, etc., in such a way as to make it unsafe for traffic, the foreman must put out a flag and torpedo at a distance of 90 rails or 15 to 20 telegraph poles from the point of work, these signals being put in both directions on single track. If trains must stop, a red flag and one torpedo are placed; if they are only to slacken speed, a green flag and two torpedoes are used. A man should be put in charge of the "stop" signal, being provided with tools for doing track work in its vicinity, but sometimes this is only done when the flag cannot be seen from the place where the gang is working. The man should work at some little distance within the flag limit, so as to be ready to attract the attention of the engineman if he should fail to observe the signal. The same signals are used in case of any obstruction on the track, lamps replacing the flags at night. When one gang of trackmen, bridge men, etc., passes another, the foreman of the passing gang must ascertain what signals the working gang has put out. Except in case of emergency, no repair gang must work between another gang and the latter's flags; if it is necessary to occupy the track in such a position, the second gang must put out its own flags in the usual way. No work that will obstruct the track or interfere with the passage of trains must be undertaken in foggy weather, or in times of exceptionally heavy traffic. The foreman must have his gang clear of the track, and the track in safe condition 10 minutes before the time at which a regular train is due, except when the train is late and the permission is given by telegraph or written order. The foreman must be ready for extra trains at any time. He must look out for signals carried by the trains, the principal train signals being the following:

Train Signals.

Two green flags by day or two green lights (showing in front) by night are markers to indicate the rear of the train, and if these are not shown the indication is that some of the cars have broken away or the train has parted.

Two red tail lamps are carried on the rear car at night (these lamps having a green lens at front and side and a red lens at the back); also a red light on the rear platform of a passenger train and on the cupola of a freight train caboose, The engine has, of course, its headlight burning at night.

Two green tail lights are carried on the rear of a yard engine at night, except when it has a headlight at each end.

Two green flags by day (or lights by night) on the engine indicate that another section of the train is following on the same schedule time. The engine of the last section of any train carries no such markers.

Two white flags by day (or lights by night) indicate an extra train.

A white light on the platform of a passenger car, roof of freight car or

rear of tender, indicates that the train or engine is backing, the engine then carrying a green flag or red tail light on the bumper beam.

Season's Work.

As to the seasons for doing the different kinds of work, it may be said that general improvements, tile drainage, reballasting, etc., can best be carried on from late spring to late autumn, but all such work should as far as possible be planned and arranged for beforehand, so that the track may not be disturbed for reballasting just after the section gang has completed a thorough surfacing. Work trains and floating gangs for ditching, ballasting, widening cuts, etc., and special gangs on new interlocking plants, rearrangement of yards, repairing or building structures, etc., may be worked at any time from the end of one winter to the beginning of another. For the ordinary work on the sections no set rules or program of procedure can be formulated, as the requirements vary in different sections of the country. In general, however, the year may be divided into four seasons, and the work done during these seasons practically as outlined below:

Spring.—As soon as the winter is over, all likelihood of snow past, and the frost coming out of the ground, the work of reducing and removing the shims should be commenced. The frost will, of course, remain longer in the roadbed in cuts than on exposed banks. Low joints must be raised, spikes driven, bolts tightened, cattleguards and road crossings cleared and repaired, ditches cleaned, fences repaired, portable snow fences taken down and piled, rubbish and old material cleared from the right of way, and the necessary lining and surfacing done to put the track in good condition previous to the more extensive work later in the season. At the same time sign posts and telegraph poles are straightened, fences repaired, and sidetracks and yards overhauled. The gang (if not already increased) is then increased to its maximum number, and the work of renewing ties is commenced, the ties having previously been distributed on the section. About four days a week should be spent in putting in the ties, all ties being fully tamped as soon as they are in place. The other two days are spent on other necessary work. On some roads the tie renewals are done quickly at the beginning of the season, while on others this work is spread out through the season. The former is by far the better plan, as the continued disturbance resulting from the latter plan is very detrimental to the maintenance of good track. When the ties are all in, the work of thorough lining and surfacing preparatory for the heavy summer traffic is commenced. The lining is done first, on account of the bad line resulting from the tie renewals, but the surfacing should follow very closely. The gaging is done at the same time. Ballasting is done after the new ties have been put in. In surfacing, care must be taken not to raise the track too much, but only to give a uniform surface, the track being raised out of a face only about once in four or five years.

Summer.—Besides the work of surfacing, rail renewals may be done at any convenient time between spring and winter. The new rails are sometimes laid before the ties are renewed, but it is better to put the ties in first and have them thoroughly tamped up, especially if there are many bad ties. A general inspection of spikes, bolts, nuts and nutlocks is then to be made. All worn, bent, broken or improperly driven spikes are removed, the holes plugged, and new spikes are driven. Broken or loose

bolts are made good. Switches and switch connections, frogs, guard rails, etc., need to be carefully inspected and repaired. As fast as the regular surfacing is completed, the ballast should be dressed to the standard cross-section, and the toe of slope lined to a "grass line" about 5 ft. 6 ins. from the rail. Tile drainage, correction of signs, and general work not interfering with the track itself can best be done during the summer. Spare time can also be spent in trimming up yard tracks, and clearing yards and station grounds.

Autumn.—Weeds should be cut at least once a year, and the best time for this is just before seeding. The grass on the right of way should be mowed, bushes cleared and trimmed, and in cases where fires cause trouble a fire guard may be formed by plowing a narrow strip about 50 ft. on each side from the track. Burnt or decayed trees likely to fall near the track should also be removed, and the dry brush, old ties, etc., may now be burned. Old material should also be cleared up. About a month before the commencement of the winter or rainy season, a general surfacing, lining, gaging and dressing of the track should be done, starting at the farther end of the section and working steadily to the other end. The track itself should be put in condition at the same time, and the spikes and joints seen to. When this is done, ditching must be undertaken, the ditches being cleaned out and improved where necessary to give the necessary width and grade. The more thoroughly this work is done the better will the track be during the winter. Trenches should also be cut under switch rods to prevent water or snow collecting around them and freezing. The culverts and waterways must then be cleared of brush and obstructions, and any signs of scour or undermining looked for, while streams should be examined above and below the culverts and any obstructions removed. After this there is plenty of work to be done in cutting and burning weeds, repairing fences, repairing and erecting snow fences and stacking additional portable snow fences where they will be needed. Track signs and telegraph poles have to be inspected, and cattleguards and crossings cleaned up. Yards and sidetracks may profitably be cleaned, drained, leveled up and repaired before the snow falls.

Winter.—The winter work, with reduced track forces, is largely that of inspecting the track and making small repairs; also looking after the spikes, bolts, frogs and switches. Such work will occupy the time between snow storms or in fine weather. During snow storms the switches, frogs and guard-rail flangeways must be kept clear, as also all signal and interlocking connections. Salt is used to melt the snow, but oil should afterwards may be applied to all moving parts, such as slide plates, bell-crank levers, etc., as the salt water has a tendency to rust the iron, making the parts move hard. In heavy snow storms the section men must work in clearing the track and help the snow gang or shovelers. In the intervals of fine weather rails, ties, lumber, fence material, etc., may be distributed, ready for spring work. Heaving of the track by frost has now to be expected, and proper precautions must be taken to keep the track in surface by shimming, while in very bad places blocking may be necessary. The ditches should be examined as soon as any thaw sets in, and kept clear of ice or packed snow, so as to allow free passage for the water.

Lining.

The true alinement of track is essential for economy of maintenance

and for the easy and safe running of trains, as kinks (even though slight) in tangents or irregularities on curves cause an unpleasant side surging motion of the cars, which in aggravated cases may even lead to a derailment. All kinks of rails should be taken out with the rail-bending machine, and all rails for curves should be bent in this machine, care being taken to have the ends bent uniformly with the body of the rail, which is not always done.

On new work, stakes are set by the engineer at intervals of 100 ft. on tangents and 25 to 50 ft. on curves (according to the sharpness of the curve). The foreman sets his gage on the track at each stake, and the men throw the track by means of bars until the center mark on the gage is over the center tack in the stake. When this has been done at four or five stakes, the men go back and throw in the intermediate points, the foreman lining them in by his eye. When the road is in operation the track centers soon become destroyed or displaced, and the effect of the traffic is to cause the track to shift more or less both on tangents and curves, and especially at the ends of curves if transition curves are not used. If the foreman's eye alone is then depended upon for lining, there will gradually develop considerable changes from the original alinement, including modifications of curves and swings on long tangents, since no trackman's eye is sufficiently good to run in curves or long tangents unassisted by an instrument. The varying ideas and ability of individual men will thus result in giving a line which is not satisfactorily true. In lining track after surfacing, the lining bars must not be stuck in the ground at too great an angle, or they will raise the track in moving it, and so spoil the surface. If the track is hard to move, all the bars should be stuck firmly in the ground, so that no one of them will slip, and then all the men should pull steadily together as the foreman gives the word.

In any thorough realinement of a piece of track, the transit should be used, and the track centers marked by tacks in stakes, as in new work. For double track the foreman may have a special gage for lining the inside rail of the second track from the track already lined, all measurements being made from the gage side of rail heads. Center stakes should be set every three or four years, and those on sharp curves tested once a year. Iron plugs, 24 ins. long, may be used for curve centers, while in some cases permanent monuments, consisting of granite blocks or posts, are set at the P. C. and P. T., or around the curve, from which remeasurements can be taken to check the alinement.

For the ordinary lining work on the section the foreman's eye is mainly relied on, but a careful man will assist his sight by means of a sighting rod or target. For short sights, as in bent rails, he should bring his eye close to the rail, but for longer sights he should stand up at some distance from the work, so as to avoid putting a swing in the track. He may sight by means of a rod or target fitted to a track level or gage, a graduated arc on the gage giving the vertical setting of the rod. The target is screwed into the top of the gage, with its center line directly over the gage side of the rail. In all work of this kind, one line of rail is taken as the "line rail," and all lining is done on it, the other rail being conformed to the line thus given in the subsequent operation of gaging. After proceeding ahead for some distance the foreman should turn and sight back as a check upon the accuracy of his work.

If there are many bad "swings," the foreman should get the roadmaster to have them lined in by a transit. With transit sights of 1 to 5 miles, as on long tangents, the center line may be sighted from the transit upon a foresight target made up of a board 36 x 18 ins., painted red and white, and placed over the track at a water tank, etc., at a sufficient height to clear trains. Center stakes and tacks may then be put in at intervals of about 750 ft. (or opposite every fifth telegraph pole). The transit is then placed over the gage side of the line rail at the starting point, and a foresight taken on a rod set at the gage side of the rail and attached to a track gage, whose center line is over the center tack of one of the stakes. Intermediate sighting is then done on a small target on a second track gage, which is moved along about 50 ft. at a time. A lining gang for this work would consist of about three men ahead of and five behind the moving target. A useful device to expedite transit work in lining curves, etc., in maintenance-of-way, is shown in Fig. 203A (p. 318). It is a small red and white flag or target, used as a backsight flag, being driven into the stake or tie just back of the tack marking a point. Its use saves the time otherwise lost by the whole party when a man is sent back with rod or pencil to give a back sight. With two or three of these flags ("standard section men," as they were locally termed) it is said that three men can make about as much time rerunning curves and tangents, as four men can make without them. They give a well-defined sight, even at long distances; stand so low that passing trains do not knock them out, and are gathered up at night after the work is done. A smaller, lighter and cheaper flag or target is of 1/8-in. iron, of triangular form, 4½ ins. high (including a ½-in. point) and 2¾-in. wide on top, with top corners of 5-16-in. radius. It is painted red and white, and the point is driven into the ties.

The foreman should check the curves occasionally to see that the proper degree of curve is maintained uniformly. To do this a cord or string is stretched tight with the ends touching the gage side of the head of the outer rail, and the distance from the middle of the cord to the rail head carefully measured. This distance in inches divided by the middle ordinate for a given length of chord of a 1° curve gives the degree of the curve tested. The middle ordinate for different chords (or measured strings) for a 1° curve are given in Table No. 21.

TABLE NO. 21.—MIDDLE ORDINATES FOR CHORDS OF VARIOUS LENGTHS.

Length of chord.	Middle ordinate for 1°.		Length of chord.	Middle ordinate for 1°.	
30 ft.	¼-in.	.25	62 ft.	1 in.	1.00
44 ft.	½-in.	.50	100 ft.	2⅝ ins.	2.625
50 ft.	⅝-in.	.625			

This table also gives the necessary ordinate for bending rails to a curve of given degree, the middle ordinate being ¼ in. for 1°, as described under "Bending Rails."

In lining curves in regular section work, the foreman takes a cord 62 ft. or 100 ft. long, and at a part of the curve which seems to be true he measures chords along the gage side of the outside rail (or outside of inner rail if the rails are worn), and measures the middle ordinate. Having thus ascertained the middle ordinate, or having obtained it from such a table as Table No. 22 or 25, if he knows the degree of curve, he commences at the point of curve (or point of circular curve if there is a transition curve) and

measures chord lines from each middle ordinate, thus getting chords at intervals of 31 or 50 ft. The actual ordinates should be recorded on a slip of paper or on the rails, and when the entire curve has thus been checked it may be lined to give the proper uniform ordinate all around.

The outside rail should be taken as the line rail, beginning some distance back on the tangent, if this is not the line rail on the adjacent tangent. This rail should be thoroughly spiked, so that it will remain in position for lining the gage rail. When the curve has been lined, the ballast should be cleared away from the ends of the ties on the side to which the track must be thrown in correcting the line. The lining should be done before the surfacing. (See also "Curves" in Chapter 18.)

Gaging.

This is done immediately after the lining, and consists practically of lining the "gage" rail by measurements from the "line" rail by means of a track gage and level. The lugs or stops at one end of this gage are brought tightly against the latter rail, the gage rail being then moved to bear against the lugs at the other end. The gage rail is firmly spiked as fast as it is set in position, and as the line rail has already been securely spiked both rails are held firmly to the ties in readiness for the work of surfacing or raising track, which is the next operation.

Surfacing.

This is the most continual work done upon the track for maintenance. A common and troublesome cause of bad riding track is an irregular surface, with sags, low joints, bent rails, and short depressions and humps in the roadbed. These defects are due to light rails, weak fastenings, poor ballast, insufficient tamping, rails out of level transversely on tangents, and generally faulty or insufficient work of maintenance. The remedy for this is surfacing, or putting the rails and track in a uniform plane. In the general surfacing done each year, the track should be raised only just enough for proper tamping, but great care is required to prevent the sectionmen from raising it too much. In stone, slag or coarse gravel, a thorough tamping can rarely be done without raising the track from 1 to 2 ins. In sand, earth, cinders or poor gravel, a raise of ½ to 1 in. may be made by tamping without disturbing the bed of the tie. This work should be done immediately after tie renewals in the spring, and attended to again before the winter. It should also be looked to immediately after the laying of new rails, so as to prevent the rails from being surface bent by trains running over them when they are not uniformly supported, as it is almost impossible to take out such vertical kinks. When new rails are laid the track should be raised enough to allow all ties to be tamped to give an even bearing. The freezing of water in the ballast or roadbed in winter causes "heaving," the effect of which is to raise the track irregularly. As the frozen ballast cannot be tamped, shimming or blocking has then to be resorted to in order to bring the track to surface.

The track level and gage should be frequently used in surfacing, and no foreman should be allowed to work under the idea that his eye is superior to any instrument. The track level, however, merely indicates local defects in surface, and there is, unfortunately, no instrument in general

use which will show the general condition of the plane of the surface. Certainly no eye can detect a general irregularity in this plane in the same way that it can detect a general irregularity of line in the shape of swings, etc. The only way is to sight one rail into a uniform plane, and then to bring the opposite rail up to the same plane by means of the track level. As proper surfacing and superelevation can only be given with a correct spirit level, this tool should be reversed occasionally on a level piece of track to see that the bubble is always in the center. If not, the level should be sent to the shop for repairs. The best way to put track up to surface is to use a sighting board and blocks. The board is about 10 or 12 ins. wide, long enough to rest across the rails; and it is painted black, with a white line, say 4 ins. from the bottom. This is placed on the rails at a point beyond the part to be raised, where the track is already in proper surface. The foreman has a wooden block, 4 ins. high, which he places on one rail at a point three or four rail lengths on the other side of the part to be raised. A similar block is placed on the rail between the board and the first block, this second block being moved from point to point and the track raised at each point until the top of the block is sighted by the foreman in line with the first block and the stripe on the board. The raising is done by bars and tamping; although for a considerable raise jacks may be used. This method fixes the surface of only one rail, however, and the other side of the track must then be brought up to the extent shown by the track level. The usefulness of this method of sighting, may, however, be extended by having the two blocks (or targets) each mounted on the middle of a track level, the sighting showing the longitudinal surface, and the level bubble showing the transverse surface.

In surfacing or raising, the track should never be brought up above the level of grade stakes or of bridges in the expectation that the traffic will settle it down to the exact grade. If the raise is at all heavy, the joints are raised first, then the centers, and then the quarters; but if it is light, the joints are raised first, and then the thirds or "long quarters," which will bring the centers up properly. The track level is then used at all joints and centers, and the opposite rail brought up as required. The raise should extend only over such a length of track as can be tamped between trains, and neither side should be fully tamped until both sides have been brought to surface. In surfacing on curves, the inner or lower rail is taken as the sighting rail. If there are humps or high places, as well as low places, the work of lowering to surface is more troublesome, and it may be necessary to shift the ties. In this case the ballast is shoveled out between ties 1 and 2, 3 and 4, 5 and 6, etc., and ties 1, 3, 5, etc., are shifted into the spaces thus formed. The beds of these ties are then leveled off as required, and the ties shifted back into position; ties 2, 4, 6, etc., are then knocked into the space dug out, and have their beds leveled off in the same way, being then put back into position. The ties should be well tamped, and the lowered piece of track tested for surface after some trains have passed over it.

With earth or mud ballast the section gang has to be continually at work surfacing, as the material will not give a uniform support under traffic, but parts will go down while other parts remain firm. If the force is sufficient the track should be surfaced and tamped in the usual way; but if the section is long and the number of men allowed is small (which

is frequently the case on roads having earth ballast), then there is not time enough to fully tamp all low ties and low spots to proper surface. In such cases the tamping must be done partly from above by the trains, instead of merely from below by the tamping bar. The jacks or raising bars are put under the part to be raised, as far from the finished part of track as is possible without causing the rail to sag between the jack and the finished track. The low track is then raised above the finished or desired surface by an amount varying from ¾-in. for small lifts to 1½ or 2 ins. for lifts of 4 to 5 ins. Earth is then shoveled under the ties and packed by the shovel blades, and by bars or shovel handles at the joints. The jacks are then removed, the track sighted for surface, and rectified if necessary. The track should be lined up before the first train passes. The train will drive the ties down to surface, and after it has passed the surface should be finally sighted, and the ballast then well shoveled under the ends of the ties, leveled and dressed to shape for proper drainage. If one man does all the filling, so much the better, as no two men will fill in alike, so that the resulting surface will be better if but one man does this work, while the others handle the jack or raising bars and attend to the dressing, etc. The foreman is the best man to do the filling, as he should observe what parts of the rail require the most raising. In work under such circumstances it is simply a question of how to keep the track in reasonably good running condition, without much regard to appearances, or as to the best possible way of doing the work. In all such cases, however, good men who are familiar with the work will devise many useful little plans for themselves, while new men, accustomed, perhaps, to good ballast and large gangs, will find it difficult to get satisfactory results under the new conditions. Mention may be made of the Patterson surfacing machine which has been tried experimentally. It consists of a blower mounted on a frame which rides on one rail, and is driven by hand. The machine itself has two vertical pipes uniting in a bottom shoe, one pipe being connected with the blower by hose, and the other having a hopper on top for the gravel, sand or other ballast. The track is raised by jacks, and the ballast blown in under the tie. It can make a raise of ¼ in.

Renewing Ties.

The new ties are usually distributed by work trains at convenient times during the winter, so that all may be on the ground soon after the frost is thoroughly out of the roadbed. The distribution is done under instructions from the roadmaster or foreman as to the places for unloading and the number unloaded at each place. If the ties are distributed in small lots or during a dull season, the tie car may be hauled in a local or extra freight train. In some cases the ties are not distributed along the section from the cars, but are unloaded in lots at certain points and thence distributed by push cars. The old ties to be renewed should have been previously marked conspicuously by the roadmaster, and only ties so marked must be renewed. The work should be done before or immediately after new rails are laid, so as to give a good substantial bearing to the rails, all new ties being thoroughly tamped. Old joint ties may be left under new rails if they are sound and of suitable size, but all old ties left in the track should have open spike holes plugged. The work of renewing ties should be commenced as soon as possible after the frost has left

the ground, as the ballast is then loose, while the men can work to better advantage than in the summer. Then by the time the heavy summer traffic begins, the new ties will have become well settled, and the track will have a substantial bearing, and will require but little maintenance. If the ties are put in late, and the season is wet, they do not get properly tamped, so that they may have to be shimmed in the winter; the renewal of shims and fixing up of the roadbed in the spring then delays the new work of tie renewals. Whenever the work is commenced it should be pushed steadily along and completed as soon as possible, for continual renewals of a few ties at a time all through the season prevent the track from being well settled and consolidated. This continual disturbance results in an increase in maintenance expenses and train expenses.

For tie renewals in gravel ballast, the ballast is cut away from the ends of the ties and loosened along their sides. The spikes are then drawn, and the rails raised slightly by jacks, just enough to allow of the old tie being knocked out and a new one slipped in on the same bed. The ballast should not be dug out under the tie, unless the new tie is of greater thickness (which it should not be), as the less the tie beds are disturbed the better for the maintenance of the track surface. This general rule may, however, be modified where only one or two ties are to be renewed in a rail length, but in this case a loosening of the side of the tie bed will usually enable the old tie to be taken out and the new one put in without much disturbance of the bed, and without the disturbance of the adjacent track which is incidental to raising by jacks. With stone, slag, or coarse gravel ballast, which is liable to fall onto the tie bed when the tie is removed, it is necessary to dig out the ballast at one side of the tie, and to knock the tie sideways into this trench. Some foremen prefer this plan with earth or common gravel, but the amount of digging required is liable to disturb and loosen the ballast. This plan may, however, be employed when two adjacent ties have to be renewed. If the ties are not uniform, the larger ones should be selected for the joints and for curves; and the wider end should be placed under the outer rail on curves. The ties should be properly spaced, placed square across the track (or radially on curves), and their ends should be lined at one side of the track. It is rarely economical to turn old ties, except where tie-plates are to be applied, and then it is probably better to turn the ties than to adze out new seats on the old worn faces.

If the traffic is heavy, each tie should be tamped and have the outside spikes driven at once. Otherwise, a number of ties may be renewed in succession; one man going ahead to cut the earth or gravel from the ends of the ties, two men pulling spikes, and two men raising the track with jacks. If only one jack is to be had, the rail first raised should be blocked up, and the jack then put under the other rail. When 20 or 30 ties have been thus put in, three men are sent back to do the spiking, one holding up the ties with a bar and two driving the spikes. The new ties should be tamped each day as put in, the tamping being done thoroughly with a bar or pick. The ballast is then filled in between the ties and dressed to proper shape. If the new ties are shovel-tamped, or only partially tamped with bars, and then left to be finished a few days later, the old ties will be disturbed, and a soft spot probably caused, especially if rain falls before the tamping is done. No train should be allowed to pass over untamped track, the foreman taking it for granted that it is safe.

At the end of each week the ties removed should be properly piled on the right of way, at a convenient distance from the track if they are to be loaded on cars, or midway between the track and the fence if they are to be burned. They should not be left in the ditches or scattered about the right of way. Ties may be burned in small piles of 5 to 10, or in large piles of 50, but the former is usually the better and safer plan. The piles should not be near the track, as the intense heat is injurious to the paint and varnish of cars. Large piles should be burned in damp weather to reduce the danger from fire, and in all cases the burning piles should be watched to prevent fire from spreading to fences, fields, etc.

Tamping.

The only way to maintain track in good surface is to have the ties well and thoroughly tamped. Tamping picks are used for stone, slag, or coarse clean gravel; tamping bars are used for earth, cinders and ordinary gravel. In tamping with bars there should be an equal number of men on each side of the tie, standing opposite one another and striking in unison, so as to pack the material fairly and not drive it out at the opposite side of the tie. Shovel handles make fairly good substitutes for bars in light work, or where the extent of the work and the smallness of the gang prevent thorough hard tamping. Shovel blades, however, should never be used for tamping, except at the middle of the tie in loose ballast, as the shovel has not the force or weight necessary to pack and consolidate the material sufficiently for good substantial work. This may be stated very emphatically, though many trackmen working in gravel or earth ballast believe otherwise. The joint ties should be tamped first, and somewhat harder and higher than the others, but not so hard and high as to cause the traffic to crack the splice bars. The most thorough tamping should be directly under and for about 8 or 12 ins. on each side of the rail, and tamping from the ends will assist in getting a good firm bearing under the rail. Each tie should be fully and properly tamped before the men leave it to tamp another. The middle of the tie should not be tamped too hard, or the track will have a tendency to rock laterally, and the ties may be broken. When the track has once become center-bound in this way it is difficult to effect a remedy without disturbing the entire track, involving considerable work and expense. The ties at frogs, switches, crossings, etc., should be specially well tamped.

Raising Track.

About once in three to five years the entire track will be required to be raised out of face or brought up to a new surface. At such a time (as well as in raising out of sags of any considerable depth) grade stakes should be set to give the elevation of the top of the rail. The stakes should be 100 ft. apart on tangents, and 25 to 50 ft. on curves, the curve stakes giving the elevation of the lower or inner rail. Ballast should then be distributed for raising the track. When in raising track (or changing grades), where good expensive ballast is used, there would be 6 ins. greater or less depth of ballast under the ties than the standard depth, then the roadbed should first be raised by filling (or cut down), so as to retain a practically uniform depth of ballast and so prevent the waste of ballast as filling.

In raising, jacks should be used under each rail, and both sides of the

track brought up and tamped simultaneously; it is bad practice to raise and tamp one side first, and then bring up the other side by the track level. The raise should not exceed 6 ins. at any one lift, the 6 ins. of ballast being well tamped, and then another raise made. The jacks should be set about 2 ft. from the joints, so as to bring the joints up level and avoid bending the splice bars. They should never be set on the inside of the rails (see "Tools"). The track should be raised about ½ in. or ¾ in. above grade (according to the quality of the ballast) and well tamped, on account of the tendency of new track to settle. Every foreman has his own ideas as to the proper course to pursue in tamping a raise, but a good plan is to first tamp the joint ties (bringing them a little high), then the center tie, the two quarters, and the intermediates; finishing off again at the joints. An incline or "run-off" should be made, connecting the old with the new level, this being long enough to allow trains to ride easily over it, and to prevent the bending of the rails. If the work is extensive and the section gang is assisted by a floating or work train gang, a part of the regular gang should follow behind the raising gang, to finish the tamping, surfacing and dressing.

Moving Track.

In some cases, as in building additional tracks or improving alinement, it may be desirable or necessary to shift the existing track to another part of the roadbed. This may be done in either of three ways: 1, by tearing up the track and relaying it on the new location; 2, by sliding the track bodily in sections; and, 3, by throwing the track with bars. Considerable work of this kind has been done in the four tracking of the New York, New Haven & Hartford Ry. In one place, where the new roadbed was 6 to 9 ft. above the old one, the two tracks on the latter were shifted bodily 20 or 30 ft. on skids to the new roadbed, the old bed being then raised by filling to correspond with the new grade. The length of this stretch of track was 8,930 ft., including two bridges, at which the track had to be cut. On the open line, the track was cut at lengths of five rails by unbolting the splices; planks were then spiked to the ties to keep them properly spaced, and each length of track was then slid laterally on six skids made of rails spiked to spruce stringers, 6 x 8 ins. The force aggregated 260 men distributed as follows; 1 foreman and 35 men first raised the tracks ready for skids (using six jacks to a five-rail length), and drew all spikes from worthless ties, so as to leave them behind and avoid handling useless material; 1 foreman and 150 men then moved the lengths of track by block and tackle to the top of the new bank, unloaded ballast and roughly surfaced the track; 1 foreman and 75 men then made the connections between the lengths and lined and surfaced the track. A work train ran back and forth distributing material. The skidding and lifting by the second gang averaged about three minutes per length of track. Work was commenced at 7 a. m., and the track was turned over to the operating department by 5 p. m. The second track was afterwards moved in the same way. The initial cuts were made where the new bank was only 2 ft. above the old bank, and the end pieces of track between the undisturbed track and the first lengths to be moved were thrown to the new alinement by lining bars. In some cases, owing to the curves and bridges, some of the five-rail lengths had to be moved longitudinally, even as much as 3 ft. For this purpose the skidding gang of 150 men had 75 bars; these

were placed horizontally under the rails and held by a man at each end of each bar. The section of track was thus readily raised and moved forward or backward by easy movements. The lengths on the bridges were left until the last, the spikes being then drawn and the rails carried over and spiked to the floors of the new structures.

Under ordinary methods of moving track, the spikes would have to be drawn, rail joints disconnected, and ties and rails carried about 25 ft. and relaid in the new position; the ties would then have been spaced and lined, and the rails bolted, gaged and spiked as in new tracklaying. This plan would usually involve much more delay, and some considerable loss and breakage of bolts and spikes, though this might of course be reduced by carefully planning and laying out the work, in the same way as was done for the "skidding" method. On the other hand, the skidding is likely to result in surface or line kinks in the rails, bent splices, and displaced spikes, making it difficult to put the track in proper condition for service in its new location. If the track is for only temporary use, or for work trains, as on parts of the work above described, the skidding method may be adopted to advantage. For permanent work in four tracking a double track road, it would be far better in the end to build the two new tracks complete in the usual way, then make connections with the old track at the ends, and abandon the old tracks, which can then be removed and the roadbed improved or rectified as required.

It is sometimes considered that if the track is to be moved less than 20 ft., it is most economical to throw it to the new position by means of lining bars. Stakes should be set for the new alinement, and driven so as to be below the base of rails. The length of rails on the new and old alinement should then be carefully measured with a steel tape, so that rails may be cut to fit if there is any difference. The new grade should be leveled and ballasted, the ballast being given an incline on curves, so that when the track is thrown it may be at once ready for traffic. If the track is to be thrown for a distance less than the length of a tie, then the part of the old roadbed which will be included in the new bed should be dug out below the ties. If the distance is greater, this need not be done, but the ballast should be loosened between the ties. Where the rails are cut, there should be six men (three cutting and three drilling). Having first disconnected the rails and moved the spikes on the side opposite to that towards which the track is to be thrown, two or three gangs working one behind the other, should throw the track, not moving it more than 12 ins. at each throw, so as to avoid bending rails and splice bars or twisting the ties. Other gangs should follow with the lining and surfacing as soon as the first part of the track is in its new position, but before the tamping is done, two or four men with sledges should tap the ties to proper spacing and square with the rails. Trains should be flagged to pass slowly over the new track until it is thoroughly finished and in substantial condition. The work may be done at once, in a time of light traffic, or gradually (between trains) during the week; proper curve connections being maintained at each end and all trains being flagged.

Handling Rails.

There is probably no one thing about which the average track foreman complains more bitterly, or which is more often offered as an excuse

for rough-riding track, than kinked and surface-bent rails. The causes for such bending are numerous, but the most fruitful of all is perhaps the way in which the rails are unloaded, and the practice in this respect differs on various roads. It may be said right here, however, that rails should not be dropped or thrown from the side of the car upon the roadbed; and that if they are necessarily thus dropped, care should be taken to see that they are dropped on soft, level places, and so that they do not strike ties, boulders or other rails. If unloaded from the end of a car, the rails should not be allowed to slide off and drop upon ties. Neither should they be unloaded from a moving train, except in cases where the train moves ahead a rail length at a time and its motion is used to pull off the rails.

In unloading from the side of a car the rails may be unloaded at one place in a pile, by means of skids, and then distributed to the required points on push cars. The skids may be two rails or two oak sticks, about 3×4 ins., 6 to 8 ft. long, faced with iron and having each a clamp at the upper end to fit on the side of the car. The skid may have a small pulley set below the face at the upper end, a rope passing round this and having a hook at one end to sustain a rail. Two men on the ground lower the rails by these ropes and also shift the skids as the train moves ahead. The rails may also be lowered at the side of the car by some such device as the Byer's unloader, which consists of three brackets or straps hooked onto the side of the car, each bracket carrying a horizontal roller at its lower end. The length of the brackets is from 5 to 18 ins., the shortest being at about the middle of the car and the longest near one end, so that the three together form an inclined roller-way along the side of the car. Men on the roadbed receive the end of the rail and lower it, not allowing the rail to drop.

In unloading from the end of a car, the rails may be simply pushed off the car, or hauled off by a rope. The rope (or chain) should be 15 ft. long, having an L hook or a clevis at one end and a claw hook at the other; the L hook is put through the bolt hole of a rail on the car, and the claw hook placed over the edge of a tie. The train then moves ahead and the rail is thus hauled off. Two men attend to the ropes, and there should be men to lower the free end of the rail. Sometimes six men (or eight for long rails) are on the car, and with tongs slide the rail off, while eight men on the track haul the projecting end outside the track until it rests on the ground, when they move up to the car and take hold of the other end, which they carry out in the same way, laying the rails either upon the ground or upon the ends of the ties. The men should not be permitted to drop the end of the rail, but there is some liability of injury to the men, owing to carelessness or accidental slipping causing them to drop a rail. To prevent improper handling of the rails it is a good plan to have a tail gate attached to the end of the car floor, or to the end sill by iron claws with cutting edges, or by other means; the lower end of the gate trails along, resting upon the rails. With gondola cars a second shorter gate may be attached to the top of the end of the car, having its lower end resting upon the longer gate. The rails may be pushed off by forks or hauled off by ropes as the train moves ahead, the end of the rail having a continual bearing on the gate until it reaches the ties. In this way the work can proceed quickly, without danger to the men.

In unloading by hand, with a train of 12 to 14 cars, two unloading gangs of eight men each may be employed. At the first stop, the gangs work from the ends of the train, throwing two rails off each car, until they meet at the middle car. The train then moves ahead one train length, and the two gangs work from each other to the end cars. In unloading rails of greater length than 30 ft. a larger number of men must be employed, but not a greater number per ton, and no more than is generally available. The Norfolk & Western Ry. finds no difficulty in handling its 85-lb. rails, 60 ft. long, only a few more men being required. Ordinary gondola or flat cars will usually suffice for carrying rails 30 ft. long, and the Lehigh Valley Ry. loads its 45-ft. rails on two 30-ft. cars. The Norfolk & Western Ry. loads its 60-ft. rails on alternate flat cars, the ends projecting over the other cars, requiring 7 cars (35 ft. c. to c. of couplers) for three loads of 34 rails each.

At yards and mills a pneumatic hoist may be used to advantage. This consists of an inverted cylinder about 6 ins. diameter and 48 ins. stroke, hung from the end of a horizontal revolving crane arm or from the end of a derrick boom. A pipe connects the cylinder with a compressor (an air-brake pump being frequently, though not economically, used for this purpose), and the operations are controlled by a three-way cock on the crane post or derrick mast. To the end of the piston rod are attached suitable chains or slings.

Relaying Rails.

In laying new rails on a section there are two principal methods of practice. One method is to lay the new rails along the ends of the ties, to fully bolt up the joints, and then to take up the old rails and throw in the string of new rails. The other method is to lay in one rail at a time. There is also a compromise method, by which the rails are bolted together in lengths of five or six, the intermediate joints being left open, to be bolted up when the rails are in the track. In either method the details of the work and the distribution of the men depend largely upon the traffic, and vary very considerably on different roads. If the track can be given up to the roadway department, either entirely (as on a length of one track on double track roads), or for a certain time by arrangement with the superintendent or train dispatcher, the relaying should be done in a similar way to new tracklaying, the old rails being first removed and the new ones (distributed along the roadbed) laid in their place.

Laying Rails in Strings.—This method is usually considered the most satisfactory where the traffic is only moderately heavy, and the work has to be done between trains, although with certain special forms of joints it is not practicable. All the preliminary work is done while the traffic is passing, and the rails then thrown in in strings as long as the intervals between trains will permit. The principal objection to this method is the difficulty of insuring uniform expansion spacing, but this can be provided for by careful supervision of the work by the roadmaster and by the employment of careful foremen and experienced men. This objection has more force for work on curves than on tangents, but here the new rails may be laid 12 ins. from the track rails; those for the outside of the curve being given more and those for the inside less expansion spacing than on tangents, at the rate of ¼-in. per 100 ft. length (that is for four joints),

per degree of curve. The bolts should also be left somewhat slack, and the expansion spacing regulated and bolts tightened as soon as the rails are thrown into position. The joints between tangent and curve rails should be left open. The spacing may be maintained, or preserved from change, during the work, by having all joint ties in proper position and driving the spikes in the slots or at the ends of the angle bars as fast as each joint is reached. Usually only one line of rails is laid at a time, but both may be laid together if desired, one gang being 10 to 15 rail lengths ahead of the other, so as to avoid interference. In any case, the second line of rails should be laid as soon as possible after the first. Care should be taken to avoid bending the splice bars by hurriedly throwing the string of new rails into position with bars. The iron expansion shims should be left in place until the string of rails has been thrown into position, and should then be removed. Two men may do this work, one raising the joint with a pinch bar to enable the other man to take out the shim. These shims should be L or angle-shaped straps of iron, 1½ ins. wide, of proper thicknesses, and those of different thickness (for different temperatures) should be kept separate. The use of wooden shims should never be permitted.

The first joint of the new string, at its connection with the old rails, will of course fit to place at once, a spike being driven at the heel to prevent the rails from being forced backward. Succeeding stretches, however, will not fit so closely, owing partly to variations in expansion and to slight variations in length of old and new rails. For this reason it is sometimes necessary to move a string of rails endways. A string of 20 to 50 rails can be moved by four to eight men, with bars placed at intervals of about six rails. They place the bars so as to get a bearing against the ends of the angle bars and pull together at a signal. If a work engine is available, a string of rails can be moved to place by the use of a 15-ft. rope or chain. When relaying rails in strings, the foreman (if near a telegraph office) should arrange with the train dispatcher to perform the work at times when it will least interfere with the movement of trains. He should then lay the largest stretch that can be properly taken care of in the time available, and have the track in shape before the next train is due. The work should not be done hurriedly.

Laying Single Rails.—If the traffic is very heavy, the most satisfactory method, as a rule, is to lay a rail at a time, keeping the track all finished up behind the gang. This method requires a larger gang, as six or eight men are required to lift and move single rails, while two or four men with bars can easily handle a string of rails. The men in the larger gang also work somewhat at a disadvantage by being more crowded, but there is the advantage that every interval between trains can be utilized. This is the safer plan under such conditions, although if the traffic is exceptionally heavy, much time may be lost in disconnecting and connecting up for each move. Safety and good work, however, are of more importance than mére rapidity of work. The gang can undoubtedly be distributed to better advantage in working on a stretch of track, and can throw out the old and throw in the new rails with greater ease than where each rail is handled singly. Under this method, also, a flagman (or two flagmen on single track) must be kept out all the time, while under the former method this is only required when the string of rails is being thrown in.

A relaying gang will usually consist of 30 to 40 men, according to the weight of rail, arrangement of work, etc., and the men should be so distributed that the different parts of the work will progress at a uniform rate. In laying a string of rails the distribution for the preliminary work will be about as follows: 8 men with 4 rail tongs stringing the new rails on the ends of the ties, 1 man adzing ends of ties level, 4 or 6 men bolting up the joints, 4 men removing two bolts from each of the old joints (or four bolts if six-bolt joints are used), 4 or 6 men pulling spikes from the old rail, 1 man plugging the spike holes, and 4 men adzing the ties where the spikes have been removed. When the string of rails is to be thrown in, the distribution will be about as follows: 4 men removing the rest of the spikes, 2 men plugging spike holes, 8 to 12 men adzing ties (according to amount of work required), 4 to 6 men throwing old rails in towards middle of track by means of bars, 4 to 6 men throwing in new rails by means of bars, 4 men spiking alternate ties (or joints, centers and quarters). The several gangs can be kept well out of the way of each other, and if both rails are being renewed together, a similar series of gangs may follow about 500 ft. behind on the other rail.

In laying single rails the distribution of the gang will be about as follows: 8 to 10 men pulling spikes, 4 men removing bolts on curves, 2 to 4 men throwing out the string of old rail, 4 men adzing ties, 8 to 12 men putting in new rails, 4 to 8 men bolting joints, and 4 to 8 men spiking. The distribution of force with gangs of about 40 men in replacing 56-lb. rails with 75-lb. rails on the Kansas City, Fort Scott & Memphis Ry., in 1895, was as follows, the new rails being put in one at a time: handling rails, 12; pulling spikes, 15; spiking, 4; nipping, 2; flagging, 2; the balance bolting up the joints. When the men handling rails caught up with the spike pullers, they went back and put on the angle bars. Then, while waiting for trains, the full bolting was done, old rails cut, and enough spiking done to make the break safe until the track was surfaced, after which the spiking was finished. Relaying rails with trains passing at intervals of a few minutes is close work, which has been done on the Manhattan Elevated Ry., New York city. There are 20 men to a gang, and they can unspike and unbolt an old rail, put a new rail in, bolt it and drive four spikes in somewhat less than four minutes. As to relaying with long rails, the Norfolk & Western Ry. has found it possible to lay 1,500 to 3,000 ft. of track per day with 60-ft. rails, weighing 85 lbs. per yd., without interruption to a heavy traffic. The force consisted of 10 men pulling spikes and throwing out old rails, 16 men putting in new rails, 4 men putting in joints, and 4 or 6 men spiking joints, centers and quarters. There was no appreciable difference in speed between the laying of 60-ft. and 30-ft. rails. The expansion spacing allowed was ⅝-in. at 0°, decreasing ⅛-in. for each 25° up to 100° F. The joint consisted of an outside angle bar and an 8-in. inside fish plate with two holes, so that no inside spikes had to be drawn. Afterwards the Churchill joint was applied.

In removing spikes and in respiking there should always be left at least 4 spikes on the inside and 6 on the outside of each rail, and only half the spikes should be renewed on curves. No train should be allowed to pass over a track that has less spikes than this or has not at least the two middle bolts of each joint properly screwed up. If the new rails

have the same width of base and head as the old ones, all the outside spikes should be removed, the inner spikes being loosened, so that the old rails can be lifted out and the new ones slipped in against the spikes. If there is a difference in the rail sections, however, the outside spikes may be drawn on one side of the track and the inside spikes on the other side, so that the new rails can be spiked to gage. This work may be done by a special floating gang or by bunching several section gangs together. Each gang then renews the rails on its own section, lines and full spikes the rails to gage, lines and surfaces the track, tightens up all bolts and finally dresses off the ballast. Where the new and old rails meet, care should be taken that the heads are in the same line, gage and level. For small differences, an iron shim under the lower rail may be used, but for larger differences, a special joint with bent splice bars is required. Where the new rails are heavier than those of sidetracks, they should be laid on the turnout and extending beyond the frog, so that the special joint will not come upon the switch ties. The rails must not be punched, nicked or slotted, as such marks are liable to cause fracture, but all holes made in the field should be drilled. Short rails are only admissible on the inside of curves (never on the outside) or as a temporary expedient on tangents, and no rail shorter than 15 ft. should ever be used.

On curves it is necessary to use a short rail at intervals in order to keep the joints from over-running, and the total length of rail required to be cut from the inside rail, if any, may be obtained by multiplying the constant 0.08552 by the number of degrees in the central angle of the curve (the minutes being either disregarded or reduced to a decimal of a foot). This gives the difference in length (in feet and decimals) of the inside and outside of the curve, and this total must be distributed over a suitable number of rails so as to avoid the use of one very short rail, and also to keep the joints as even as possible. A 30-ft. rail may be cut into two parts, differing in length by the difference ascertained as above. Then by laying the longer piece at the beginning of the outside line of rail and the shorter piece at the end of the inner line of rail, these will give broken joints on the curve and square joints at the ends. Another method is to allow a difference of 1.03125 ins. in length per 100 ft. for each degree of curve; or, in other words, to multiply 1.03125 ins. by the degree of curve and the number of hundreds of feet in the length of the curve. Methods of finding the degree of a curve in the track are given under "Lining."

It is usually required that the rails must be laid with the maker's brand on the inside (sometimes the outside) of the track. There seems to be no particular reason for this, except to provide for possible defects in the rolls by which the sides of the head may be slightly unsymmetrical, but rolls should not be kept in use until so badly worn as this, nor should an inspector accept such rails. Rails of similar section should be kept together, and this is specially to be observed in distributing old rails for relaying on third track, branch lines, etc. With old rails, this rule should not be observed where it will put a badly worn gage side against a uniformly worn gage side of an adjacent rail. Old rails for relaying should be sorted for height at the yards, and sent out in lots of the same height. They should be laid with the unworn side of the head as the gage side.

In connecting the new rails with the old to allow of the passage of a train, or in finishing up work for the day, a 15-ft. switch rail should be used, being firmly spiked to place and having its surface slightly above that of the old rail. After the new rails are laid, the string of old rails which has been thrown in to the middle of the track, may be unbolted and taken apart at leisure, all bolts, nuts, nutlocks and splice bars being carefully preserved. The old rails should not be left in the ditches, but placed beside the ballast or piled ready for loading onto the cars.

Much of the work of relaying rails is done on Sundays, and many men believe that it cannot be done on week days, on account of the traffic. This is a great mistake, and, as pointed out in the chapter on "Organization," there should be as little as possible of Sunday labor. The work can be done, and is done, as well between trains on week days.

Shifting Rails on Curves.

On track having numerous sharp curves, the service of the rails may be considerably extended by transposing the inner and outer rails. The rails are disconnected to form strings of about 600 ft. in length (disconnecting the short rails on the inside of the curve). The strings are then thrown in and passed over each other. The stretches will have to be moved lengthwise, which can be done by bearing with bars against the ends of the angle bars, or by pulling with a work engine. The inside spikes should be drawn, and in relaying to gage (on account of worn heads), the inner rail may be set in ¼-in., and the outer one ⅛-in., or according to the depth of wear of the side of the head.

Bending Rails.

On all curves of over 2°, the rails should be bent to the proper curve before being laid. If they are laid straight and then merely bent by spiking, the curve will be irregular (especially at the rail ends), and the rails will have a constant tendency to straighten. Bending rails by forcing, springing or striking with sledges should never be permitted. They should be curved in a proper rail-bending machine, and care taken to have the uniform curve continued right to the ends of the rail, as it is often found that the work is done less carefully at the ends, with the result that they have a somewhat different curve from that of the body of the rail. Where a roller rail-bending machine is used, some roads pass all rails through this, to bend the rails for curves and to take out any kinks in rails for tangents. If no bending machine is available, the rail may be curved by resting the ends on ties laid across the track, then placing a hook or curving hook under the track rail at a point opposite the middle of the rail to be bent. One end of a wooden lever or track lever is held by the hook, the lever resting on the rail and being pulled down by men holding its free end. Slight kinks in curved rails in the track may be detected by testing the curve with a cord (as described under "Lining" and "Curve Work"), and then taken out by extra spiking. In curving the rails the middle ordinate (or deflection of the middle) of a 30-ft. rail will be almost exactly ¼-in. for each degree of curve. The side or quarter ordinates are always three-fourths of the middle ordinate. Table No. 22 gives a list of middle ordinates for different lengths of rails and different degrees of curvature.

TABLE NO. 22.—MIDDLE ORDINATES FOR CURVED RAILS.

Deg. of curve.	Rails. 30-ft.	24-ft.	20-ft.	16-ft.	Deg. of curve.	Rails. 30-ft.	24-ft.	20-ft.	16-ft.
1	¼	¼	⅛	⅛	9	2⅛	1⅜	⅞	⅝
2	⅜	¼	⅛	⅛	9½.........	2¼	1⅜	1	⅝
2½.........	½	⅜	¼	⅛	10	2⅜	1½	1	⅝
3	⅝	½	¼	⅛	10½.........	2½	1⅝	1⅛	¾
3½.........	⅞	½	⅜	¼	11	2⅝	1⅝	1⅛	¾
4	1	⅝	⅜	¼	11½.........	2¾	1¾	1¼	¾
4½.........	1	⅝	½	¼	12	2⅞	1⅞	1¼	¾
5	1⅛	¾	½	⅜	12½.........	3	2	1⅜	⅞
5½.........	1¼	⅞	⅝	⅜	13	3	2	1⅜	⅞
6	1⅜	⅞	⅝	⅜	13½.........	3⅛	2⅛	1½	1
6½.........	1½	1	¾	½	14	3¼	2⅛	1½	1
7	1⅝	1	¾	½	14½.........	3⅜	2¼	1⅝	1
7½.........	1¾	1⅛	¾	½	15	3½	2¼	1⅝	1
8	1⅞	1¼	⅞	½	15½.........	3⅝	2⅜	1⅝	1⅛
8½.........	2	1¼	⅞	⅝	16	3¾	2⅝	1⅝	1⅛

Cutting Rails.

Where much cutting is to be done, as in fitting switch and frog work, etc., a portable track saw should be used, but there are many cases where a rail must be cut on the track when this device is not available. The most common practice in this respect is to nick the rail all round with a cold chisel and then to lift up the end of the rail and drop the rail so that the nicked part will strike upon the cutting block, a tie, or a piece of rail. This is usually effective, but it is a barbarous and improper way to treat steel rails, and is more or less dangerous to the men, besides having a decided tendency to put a kink in the rail. A better plan is to mark all round the place to be cut with a chisel, then lay the rail along the ties, holding one end down with a tie and putting the cutting block underneath, 4 or 5 ft. back from the cut. A bar is then placed across the rail at a point ahead of the cut, one of the track rails being used as a fulcrum and one man bearing hard down upon the bar. Another man then holds the chisel in the cut at the bottom of the web (or lower fillet), while a third man strikes the chisel a sharp blow with a hammer or sledge. If the rail does not promptly break, the chisel may be held on the other side of the rail for a second blow. The rail should be carefully measured for the exact position of the chisel cut, and the cut should be made neatly and cleanly at the required place. A rail bender may be used to break the rail by bending it at the chisel cut, and in any case the rail should be straightened after being cut, as it is likely to be kinked in the operation.

Spiking.

All main tracks should have at least four spikes in every tie, the two outer spikes being nearer the edge of the tie (on double track this should be the side first struck by the train), and the two inner spikes near the other edge, but none of the spikes being less than 2 ins. from the edge of the tie. This arrangement is designed to hold the tie square with the track and prevent slewing, but is a practical detail not infrequently neglected, the spikes being too often placed in line across the tie. Double spiking is sometimes required on curves where rail braces or tie-plates are not available; the extra spikes being required on the outside to resist the lateral thrust from the wheels. Spikes should not be driven until the ties are in position, properly spaced, and square across the track. If this is not attended to the spikes will not hold the rail properly when shifted to

proper position. The tie should be held up by bars while the spikes are being driven, but should not be lifted from its bed. Too often, however, one or two men hold up the tie so as to raise it while the spiker drives the spike, so that the tie then hangs from the rail by the spike.

The spiking should be done carefully, each spike being set vertically and driven straight down, with its shank touching the edge of the rail base. The spiker should bring the maul down with a long swinging stroke, striking squarely on the head of the spike, and keeping his hands well down, so that the handle of the maul will be approximately horizontal, as shown in Fig. 202. He should in no case set the spike sloping from or towards him, as it reduces the hold of the spike head on the rail, while the head may very likely be broken by the last blow of the maul, and the spike will be bent by being pulled out. The spike should not be set a little distance from the rail and then struck on the back to drive it

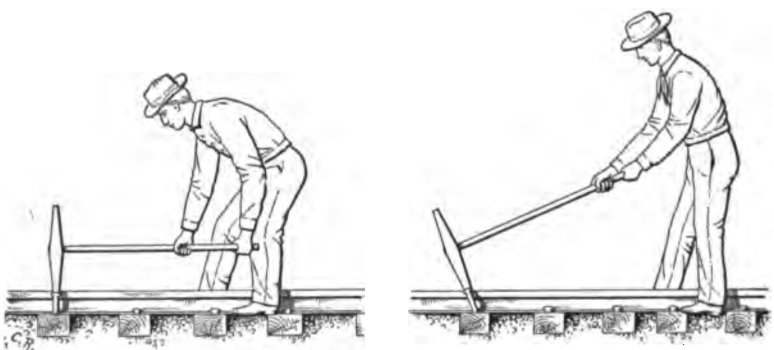


Fig. 202.—Spiking.

sideways into position, as this will enlarge the hole in the tie, weakening the hold on the spike and forming an entrance for water and moisture to rot the interior of the tie. Neither should it be driven slanting to or from the rail, for the purpose of tightening or widening the gage, but the rail should be thrown to line with a bar and then properly spiked. The last blow on the spike should be struck lightly, so as to avoid breaking the head of the spike when it comes to a bearing on the rail. At joints the spikes should be driven in the slots of or against the ends of the angle bars (the latter method is not recommended as the spikes are hard to draw), except on bridges, where free play is usually allowed for any creeping of the track, so as to avoid strains on the structure or its floor system. In warm weather, the spikes in the angle-bar slots should be driven against that side of the slot furthest from the end of the rail, thus allowing for contraction of the rail in colder weather.

In pulling spikes, care should be taken not to bend or break them, loosening tight spikes by giving them a tap on the head before applying the clawbar. Old spike holes should be filled with wooden plugs (those cut by machine being preferable); or tar or sand may be used. The new spikes may also be dipped in creosote oil, tar or resin before being driven,

but it is doubtful if this has much effect in preserving the tie from decay at the spike holes. Long boat spikes should be used where thick shims are placed between the rail and the tie, and used also for fastening road crossing planks to the ties. The section men and trackwalkers, of course, look after the spikes in the track, but the Erie Ry. has a good plan of sending two men over each section, twice a year, to drive down every spike; they also replace all spikes which are broken, are not snug against the edge of the rail, or are not in proper position in the slots of the angle-bars.

Bolting.

Rail joints should have the bolts screwed up tight as soon as put on, with nutlocks or washers in place, but the bolts will usually have to be gone over again and tightened up with a wrench in a few weeks. In tightening up bolts, the men should never put long handles on the wrenches in order to increase the leverage, as this will result in stretching or stripping the threads of the bolt or nut, so that the bolts will be weakened and loosened and the security of the joint impaired, even if the bolts are not made entirely useless. A strong, firm pull on an ordinary wrench is all that is required. In temporary bolting for construction work, slotted bolts with cotters are sometimes used to avoid the screwing up of nuts (Fig. 199). The nuts should be slackened and re-tightened in the spring (before warm weather), and in the autumn (before cold weather), so as to insure proper freedom for the expansion and contraction of the rails: as if held too tight, the rails may shear the bolts or buckle the track. All broken or damaged bolts should be at once replaced, and each joint kept fully bolted and fitted with the proper nuts, washers or nutlocks. In removing bolts while too much time should not be lost in trying to get off a rusty nut, care should be taken to see that the men do not get in the habit of saving time and trouble at the expense of damaging good bolts by knocking off the nuts and ends of bolts with a hammer, thus rendering both nut and bolt only good for scrap. If the bolts are comparatively new, the nuts may be loosened by tapping and the use of oil; and when the nut has been taken off and the bolt removed, the nut should be screwed on the bolt to prevent loss, and the nut and bolt thrown into a box or keg, and not left lying in the ballast.

Shimming.

When the ballast is frozen in the winter, it cannot be tamped, and if the track is heaved by frost, the surface is made uneven both transversely and longitudinally. This must be tested by a level for the former and by sighting or the use of a long straight-edge for the latter. In such cases wooden plates or shims must be placed between the rail and the tie, to bring the rail up to proper surface. The upper face of the tie should not be adzed to lower the rail, unless this is absolutely necessary, but the shims should be placed on the lower ties. Shimming is also required with soft ballast that is so soft after heavy rains that tamping is impracticable, the ballast and roadbed being so saturated that no other method of surfacing is effective. In some very bad cases, or in accidents, blocking must be used under the ties, but this should be avoided when possible and the foreman must see that this blocking is not forgotten and left in place,

but that it is taken out when the shims are removed, or when the ballast has dried out sufficiently to give the track a proper bearing. As the frost comes out of the ground and the ground settles, thinner shims must be substituted for the thicker ones, to prevent surface bending of the rails. The shims should never be left in place after the spring, and as fast as they are removed the spike holes in the ties should be properly plugged. Heaving is most troublesome in earth and clay, but is also felt in gravel. Where much trouble is experienced from heaving, it will usually be found economical to apply gravel ballast liberally, as the spiking and shimming injure the ties and spoil the permanent surface of the track.

The shims may be cut by the sectionmen, but it is better to use those cut by machinery, having two spike holes bored diagonally opposite one another. They are about 6 ins. wide, and the length should be at least equal to three times the width of the rail base, so as to give ample room for spiking and keeping the spikes clear of the angle-bars. The thickness is from ¾-in. to 2 ins. If a raise of more than 2 ins. is required, a piece of 1-in. to 3-in. plank should first be spiked to the tie by boat spikes, the plank being about 2 ft. long, or as long as the tie if both rails have to be shimmed. Upon this plank should be placed shims to bring the rail to the required level, these being fastened by long spikes passing through shims and plank into the tie. With specially high shimming it is well to place rail braces outside the rails, especially on curves. Where tie-plates are used, the plates should not be taken off, but the shims placed on them, and if the shimming is high, a tie-plate may be placed on its top. The tie should be adzed to give a level seat for the shims. Spiking should be attended to as fast as the shimming is put in, and if a whole rail length is to be shimmed, the joint, center and quarter ties should first be shimmed and spiked.

Fencing.

In setting fences, the distance from the center line of the track may be measured by a tape, and the line of fence set off by a cord or chain 100 to 200 ft. long, having tags at the post spacing. When this is stretched a small hole is cut at each tag as a guide to the post setters. The post holes should be of uniform depth, gaged by a stick, and the height of the post above ground may be gaged by a stick having a flat piece nailed on the bottom. This latter stick may also have notches for the fence wires to hold them at the proper spacing while being stapled to the posts. On curves the position of each post should be measured from the center of the track, and a mark made or stake driven. For wire fencing, posts may be set and temporarily braced at intervals of 40 to 80 rods (660 to 1,320 ft.), and one wire stretched first as a guide for the other posts. On the inner side of a curve the wires should be on the track side of the post, or on the track and field sides of alternate posts. The wires are attached to a straining post and set up by a stretcher, but in the absence of this tool a lining bar may be used, placed diagonally, with the top inclined towards the anchor post, and the wire being looped around the bar. In summer the wires must not be drawn too tight. With board fences, the alternate posts may be set first, 16 ft. apart, and a line of boards nailed along them will serve as a guide for lining the intermediate posts. The boards should

be on the farm side of the posts. The materials and labor per mile for a four-board fence with posts 8 ft. apart, and a five-wire fence with posts 16 ft. apart, are about as follows:

Board Fence:	Wire Fence:
660 posts.	330 posts.
1,320 boards, 1 x 6 ins., 16 ft. long, 10,560 ft. B. M.	26,400 ft. of wire at 440 lbs. per strand, 2,200 lbs.
660 battens, 1 x 6 ins., 4 ft. long, 1,320 ft. B. M.	75 lbs. staples.
250 lbs. nails.	27 days' labor for one man.
65 days' labor for one man.	

In the "Trackman's Helper," by Mr. Kindelan, it is stated that the average day's labor for one man on a six-board fence, including setting posts, is 8 to 10 panels where the boards meet on the post, or 13 to 15 panels where they lap on opposite sides of the post. On a four-wire fence, with 16-ft. panels, the average is about 15 panels. These figures vary, of course, with the details of the work and character of the men. The cost per 100 rods (1,650 ft.) for fence building and repairs, with labor at $1.50 per day, has been estimated as follows: Five-wire fence: $6 for removing old fence and posts; $16.50 for putting in new posts 3 ft. to 3 ft. 6 ins. deep, and stringing wires. Board fence: $4.50 to $5 for removing old fence and posts; $32 for putting in new posts 8 ft. long (set 3 ft. deep) and putting on seven boards; or $42 for posts 10 ft. long (set 3 ft. 6 ins. deep), and putting on nine boards. The painting or daubing of advertisements on board fences is very objectionable, and at least one road has forbidden it, making a practice of painting out such disfiguring marks.

Clearing Right of Way.

All grass, weeds and brush on the right of way should be cut at least once a year, and preferably twice a year. This should be done in the months which are most suitable, according to the latitude, but being in any case done before the seeding time of the plants. After the grubbing, cutting and mowing, the material should be raked into heaps and burned as soon as it is dry enough, care being taken that the fire is not allowed to extend to fences, trestles or adjoining land. Old ties, splice bars, tools, etc., found during this clearing up should be removed and properly disposed of. If the brush on the right of way is allowed to grow too long, it is liable to cause accidents by concealing cattle, which may stray on the track in front of a train, while it is also liable to catch fire in dry weather, such a fire being hard to check or stop. Reports of locomotives which throw sparks badly, and of fires started by sparks from locomotives, should be made by the section foreman and roadmaster. The spark arresters of locomotives should be examined frequently in hot, dry weather, when standing crops, weeds on the right of way, etc., are liable to catch fire. Where the right of way is covered with good grass, it may be mowed and used or sold for hay under the direction of the roadmaster.

The grass and weeds in the ballast and along the sides of the roadbed have also to be cut or pulled up, and this is tiresome and unpleasant work, though necessary for keeping a good looking track. A long handled sharp hoe is better than a shovel if there is much of this work to be done. Where this work is only done periodically on lines not kept in the best condition for appearance it may be economically done by machinery. On the In-

tercolonial Ry. the wings of a snow plow have been fitted with vertically adjustable steel cutters, 13 ins. deep, 9 ft. long and ⅞-in. thick. The first cut is made with the wings half open, cutting the ballast slope. The second cut is made with the wings spread to their full extent, forming the berme at the level of the subgrade and plowing the stuff down the bank. Formerly, two or three furrows were plowed with a farm plow and a pair of horses, the sods being thrown down the bank by trackmen with forks. The above machine is hauled by a locomotive, and can clean 20 to 25 miles of track in a day, making a cut on each side 3 ft. to 9½ ft. from the rail and to a depth of 2 ft. below the top of the rail. The crew consists of two men to extend or close the wings, and two men to raise and lower the cutters at crossings, switches, etc. Such a machine is specially valuable on single track roads with limited section forces, and it can be made out of a wing snow-plow, or by attaching wings and cutters to a box car. Many ditching machines can be adapted to this work, as they are made to trim off the ballast slopes.

The Sheffield weed-cutting hand-car has two toothed cutter bars (like those of a reaping machine) projecting from a frame between the wheels. The position is regulated by levers, and the knives will cut close to the ground and to a distance of 8 ft. from the rail. They fold together and swing up to a vertical position at the side of the car when passing an obstruction. It will work on level ground or on slopes, and when worked by four or six men it will cut along four or five miles per day. The machine should be in charge of a man with some knowledge of machinery and having some skill in handling such a machine. He may be given a certain length of track to look after (say 100 miles), and he should be familiar with that division. When the time for cutting comes, the section foremen are instructed to see that all portable obstructions, old ties, etc., are removed from a strip at least 10 ft. wide from the rail. The man in charge takes men from each section gang to work over the section, making a straight run over his entire division, and then returning in the same way to cut on the other side of the track. This work can be done two or three times in a season, saving much labor and expense. The machine will work best when the weeds are growing rapidly and are soft and tender. It has cut weeds 10 ft. high with stalks 1 in. thick, though it would hardly do this continuously, and such work would be hard on the men. Under ordinary conditions, however, the car can be run at good speed and the work is not severe.

Various methods have been tried for killing the grass and weeds growing in the ballast, but though such methods would be advantageous in saving the time and labor expended in the back-aching work of cutting weeds with a shovel or hoe, none of them have yet so combined efficiency and low cost of operating as to be really practicable for general work. Such a method would be specially advantageous for roads having many weeds and few section men, which is the condition of many roads in the south and west. Brine, gasoline or oil burners, steam jets and electricity are among the means experimented with in this direction. In experiments with electricity on the Illinois Central Ry., a "brush," 10 ft. long and 4 ins. wide, was made of fine bare copper wires and suspended from the front of a flat car, so that it would almost touch the ground. Another car contained an engine, dynamo, transformers, etc., steam being taken from the

locomotive. The cars were run at a speed of about 5 miles per hour, and two trips were found sufficient to kill all the vegetation, an advantage of this process being that the roots were absolutely killed. The brush was in short sections, insulated from one another, so that all the current would not be discharged through any one weed, etc., forming a more than usually good conductor. A current of 10,000 volts was found to be most satisfactory. For general work, however, the cost of this method would be prohibitive. Burning weeds with jets from burners using crude oil and compressed air has been tried on the Minneapolis, St. Paul & Sault Ste. Marie Ry. The apparatus was mounted on a self-propelled flat car and could work over 10 miles a day, consuming 15 to 20 gallons of oil per mile. A strong solution of brine, delivered from a sprinkling attachment on a water tank car was tried at one time on the Atchison, Topeka & Santa Fe Ry. It effectually killed the weeds, but caused a slime on the rails which led to slipping of the engine wheels and corrosion of the rail, and it was therefore abandoned.

In some few cases, with earth ballast, it is considered well to let the grass grow, merely cutting it down so low that it will not get on the rails. Where the weeding is done by hand, it should be extended to a "grass line," 5 or 6 ft. from the rail, this line being set out by a cord and stakes, or marked by a cutter fixed to an arm bolted to the hand car.

Policing.

This work includes the general maintenance of the roadway in neat and proper condition, and is to be attended to continually. Weeds must be kept cut, and trimmed to the grass line; ballast properly dressed and sloped; ditches cleaned; rubbish picked up, and spare material properly placed. Combustible material must be kept cleared from around bridges, trestles, signal posts, etc., dirt and gravel must be removed from bridge seats and trestle caps, and care taken to prevent ballast from working over onto the bridge abutments or falling into streets below. Large loose stones may be neatly piled around the bases of signal posts, sign posts, etc., to keep vegetation from growing. All trees that are in danger of falling on the track, or that interfere with the passage of trains or obscure the view, must be removed or trimmed. If they are on private land, and the owner objects to such work, a report must be made as to the circumstances. Any interference with or obstruction of ditches, culverts, etc., by landowners must be prevented or a report made thereon.

All old track material, links and pins, or other material from cars, old ties, rubbish, etc., must be picked up and removed from the track, all scrap being carried to the section tool house to be sorted and properly disposed of. All scrap iron, lumber, etc., must be neatly piled on platforms. New material, such as rails, ties, etc., must be properly piled or stacked, and no material should be thus piled within 8 ft. of the track.

Care should be taken to have a neat and tidy appearance of the section, with track full spiked and bolted, switches clean and well oiled, cattleguards and road crossings in good condition, fences in repair and wing fences at cattleguards kept whitewashed, ballast evenly and uniformly sloped and free from weeds, sod line cleanly cut at foot of slopes, and grass and weeds not allowed to grow too high before cutting. Sidetracks in yards should also be kept free from weeds and rubbish, old paper,

scrap, etc. Station grounds also must be kept neat. Signs must be upright and in good repair. Section houses must be clean and tidy, with tools, track material, scrap, etc., properly sorted and placed.

Every possible means consistent with general attention to track work, should be taken to keep people from walking on or at the side of the track, and from using the railway as a public path. This is specially necessary near cities, where the traffic is heavy. In such cases, where people habitually walk on the track, a liberal covering of coarse broken stone or slag, or even cinders may be laid upon the ballast, between the rails and tracks and upon the berme at the edge of the roadway. This will soon drive off those persons who cannot comfortably walk on the ties. This matter is far too often neglected, and railways are themselves partly responsible for the habit which the public has acquired of treating the tracks as a public way.

Station Grounds and Buildings.

In order to have a good reputation for the road on the part of the public, it is very desirable that the grounds at stations should be kept clean and tidy and free from rubbish. On some roads this work is delegated to the station agent, who has his men attend to it, while on other roads it is part of the section gang's work. The latter is the better plan if the force is sufficient, and if the work is done by direction of the roadmaster, the station agent not being given authority to employ the section men for this purpose when he thinks proper. On roads having stations with lawns, flower beds and nice grounds, a special force is sometimes kept to attend to them. For instance, the Boston & Albany Ry. has on each of its principal divisions a gardener with 5 to 12 men, who grade, plant and seed the grounds, and take care of them. These men cut the grass with lawn mowers, and do the weeding, trimming of shrubbery, etc. They also attend to places where the banks are graded and seeded. This force is included in the roadway department. The Pennsylvania Ry. also employs landscape engineers and a large force of gardeners and spends large sums of money in making and maintaining attractive grounds. As a result it has a reputation for the appearance of its stations. Some western roads, including the Fremont, Elkhorn & Missouri Valley Ry., have adopted the policy of making a "park" at most of the stations, sodding the ground and planting trees. It is specially important to have attractive grounds and pleasant surroundings at important stations and at junctions, where passengers may have to change trains or to stop over for connecting trains.

In all ordinary cases, however, much may be done by foremen and station agents who are not averse to putting in a little time in improving the appearance of the station grounds. The agent especially should see that the grounds and platforms are kept free from old papers and other rubbish. A plot of turf, cinder or gravel pathway, a flowerbed, a creeper on the building or on a pile of rockwork, can be had with little trouble, and have a great effect upon the general appearance of a station. The approaches and surroundings on the town side of the station should be cared for as well as the grounds on the railway side. The platforms should be convenient and in good repair and the fences kept in repair. Many a division superintendent and roadmaster can aid materially in

maintaining a good appearance along the road by fitting up a car with brake pumps and paint tanks for painting by compressed air, the work being done rapidly and economically by a few men, and being applicable to stations, freight sheds, ice houses, pump houses, section houses, signal houses, signal towers, cabins, station fences, signal posts and signs, etc., and also for whitewashing cattle guard fences, interiors of sheds, etc.

The yards, spaces between tracks, etc., at stations should be neatly leveled and covered with ashes, and should be kept in order by the section men, but strict rules should be made and enforced against the scattering of ashes and cinders from engines (which should be dumped at specified points), the sweeping of rubbish and dirt from the station on to the track, and the sweeping out of refuse and dirt from cars upon the track. Every station should have a can or bin for waste paper and rubbish, which should be emptied at intervals into a dirt car; similar receptacles should be provided at yards or places where cars are cleaned. At large terminal yards one man may be kept busy clearing up paper and rubbish. It is a good plan to have station inspectors to see that the stations, waiting rooms, closets, etc., are kept in proper and sanitary condition, and that the grounds are properly cared for. Cleanliness should be enforced in every case, but the standard of appearance will, of course, vary according to the financial condition of the road and the size of the force. The same is true of section boarding houses and tool houses.

Old Material.

In all renewals, and the periodical policing of track, cleaning up of yards, etc., it must be borne in mind that new material must be properly used and cared for, and not wasted, and also that no old material should be simply thrown away as useless. Even if really useless for railway purposes, the material, in the aggregate, has a certain selling value, which, if the material is thrown away, is wrongfully lost to the company. These remarks apply also to the wreckage and scrap resulting from train accidents and the burning of cars. Record must be kept of the disposal of all scrap and old material.

Old rails should not be left hidden in the grass and weeds of the right of way, but properly piled for shipment, as they may be used for sidetracks or branches, sold for scrap, or even made into "new rails" of somewhat lighter section by heating and rerolling. Old ties have rarely much value, but if thrown away, sold, burnt, used for cribbing, etc., all unbroken spikes should first be pulled, and when ties are burned the ashes should be raked over for spikes. In piling old rails, the splice bars and bolts should all be removed, good splice bars sorted in pairs and broken bars kept separate. Nuts and bolts, if good, should be kept together, but broken bolts should have the nuts removed and kept separate. Many spikes that now go from the track to the scrap heap (or down the bank) might be used over again if properly driven in the first place and properly drawn. Foremen should be careful to see that all track and car material, etc., is picked up regularly, and that their men do not get in the habit of flinging old bolts, spikes, etc., down the bank. In removing bolts, the nuts should be unscrewed properly, the bolt taken out, and the lock and nut put back on the bolt. If, however, the nut is so rusted or wedged on the bolt that it will not unscrew, it is more economical to

knock off the nut with the end of the bolt in it, with a sledge, than to waste time in forcing the wrench. Only good discipline and good management of men can insure the exercise of proper judgment as to when to knock off nuts in this way. If a wedged or rusted bolt has to be knocked out, care should be taken not to hit the head of the rail.

At the section tool house the scrap should be piled and sorted (as described under "Policing"), nuts taken off broken bolts, etc., this work being done in wet or stormy weather, or when the men cannot work on the track. All scrap iron, lumber, etc., must be neatly piled on platforms; car scrap, links, drawbars, couplers, etc., being kept separate. Small scrap, such as bolts, nuts and spikes, may be kept in shallow boxes or in old spike and bolt kegs. Rails may be piled on the right of way at mile posts, but should not be piled with splice bars and bolts left on. Old ties may be stacked on the right of way, until permission is given to burn them, the ties removed being piled at the end of each day's work and not left in the ditch or on the roadbed.

Under this heading it will be appropriate to refer to the treatment and disposal of the material found in the general scrap pile at the division points or main shops, which subject has been discussed by Mr. J. N. Barr, of the Chicago, Milwaukee & St. Paul Ry., in a paper before the Western Railway Club. The style of material delivered for the scrap pile is significant of the character of the men sending it, as for instance one man who is somewhat careless and finds it easier to use new material than to sort out the serviceable from the unserviceable scrap at his tool house, will send in many old bolts and nuts that are good for further use. In some cases it may be advisable to go to the expense of putting in a set of small rolls to bring odd sizes of iron to standard sizes for bolts, plates, etc.; a shear (perhaps operated by an air brake cylinder with 4-ft. lever and 6-in. jaw) for cutting rods, or even to build a small furnace for heating angles, etc., to be rerolled. Of course it must be borne in mind that while with a single large scrap pile at one large central shop it may be economical to carefully sort and handle the material, and treat it as above noted, this may not be the case with several smaller piles at divisional shops. Also, that in some cases an article made by treating scrap may be more expensive than a newly purchased article of the same kind. These are matters for the exercise of judgment and calculation in order to insure real economy.

In most scrap piles there is a great proportion of bolts. These may be sorted as to their diameters and length and stored in compartments. Stub ends of ¾-in. to 1 in. bolts, about 5½ ins. long, may be used for making track bolts, a bolt heading machine at the shops being equipped with suitable dies. Nuts may be cleaned of rust by pickling in a weak solution of hydrochloric acid, and then used again, or if damaged they may be slightly compressed by dies in a bolt heading machine and then retapped. Plates and shapes may be utilized for small plate girders to cross culverts, etc. Lining bars, clawbars, wrenches, etc., may be successfully made from scrap steel tires, and the slide plates for switches may be made from elliptic springs, the plate being heated to a cherry red and then put in a bulldozer, where it is sheared off and has two square holes punched at one operation. Old flues, which bring little as scrap, make good fencing for station grounds, posts for track signs, or grates for cinder

pits where fireboxes are cleaned out. Old fish plates or plain splice bars may be sheared to length and stamped to shape for rail braces.

In sorting, care should be taken to pick out any new or practically uninjured material which may by accident or carelessness have got in with the scrap. When sorted the stuff should be arranged so as to be easily seen and got at, but discrimination should be exercised so as not to store a lot of miscellaneous material on the chance of its being of some possible use eventually.

CHAPTER 18.—GAGE, GRADES AND CURVES.

Gage.

The gage of the track is the transverse distance between the inner sides of the rail heads, and if these sides are sloping the measurement is usually taken at about half the depth of the head. The standard gage of 4 ft. 8½ ins. is now so practically universal that no other has been dealt with in this book. It is much to be regretted that a few roads are still using a gage of 4 ft. 9 ins., as wheels which are exactly fitted for the best running on a track of 4 ft. 8½ ins. gage, may be troublesome at the frogs and switches of a gage ½ in. wider. There is, however, a tendency toward the elimination of this abnormal gage. There is practically no gage wider than the standard now remaining in this country, and the proportion of narrow gage is so small as to need little special mention in this work. Reference may, however, be made to interesting articles upon the work of changing gage, published in "Engineering News," New York, Aug. 25, 1892, and Sept. 13, 1894, and in the "Journal of the Association of Engineering Societies," October, 1884. All the extensive work has now been done, and has included the change from both the broad gage (as the 6 ft. of the Erie Ry. and the 5 ft. of various southern railways) and the narrow gage (of which the 3 ft. of the Denver & Rio Grande Ry. was among the principal) to the standard gage. There still remain, however, a number of smaller lines of narrow gage; but these are being widened gradually as they become absorbed by standard gage railways, and it may be useful here to describe the method followed on the Louisville & Nashville Ry. in widening the 3 ft. gage of a mineral branch 62 miles long.

The subgrade was widened and the trestles were strengthened, and then standard gage ties replaced every third narrow gage tie on tangents, every other tie on curves of 6° and under, and all ties on curves sharper than 6°. Prior to the day of making the change, the outer spikes for the standard gage were driven, and seats were adzed for the rails. To set the spikes, a track gage or spike setter of ½ x 2-in. iron was used. The ends of this were curved down beyond the rails, so that when set on the 3-ft. gage track, the ends rested on the tie, the ends being flattened out to 1½ ins. wide and 1 in. thick for a width of 1½ ins., this representing the rail base. A loose piece, ⅝ in. wide, attached to each end of the gage by a wire, provided for the widening of gage on curves. The "spotters" for adzing the ties were wooden bars, 3x3 ins. (rounded at the middle), with blocks nailed on the under side as gage lugs for the 3-ft. track, while under each end a strap of ⅛ x 1¼ in. iron was bent to form a rectangular loop, 5 ins. wide over all, and deep enough to touch the tie when the bar rested on the rails. The work

of changing the rails was done by the force then on the line. The one train per day was stopped, but the entire work only occupied four days. The force consisted of 180 men, exclusive of foremen, and these were organized into six gangs of 30 men each, while each gang was assigned to a division of about eleven miles, including sidings. The length of the divisions depended upon the amount of curvature to be encountered. Each gang was in general charge of a foreman, and had another foreman to look after the spiking. Work was commenced at a given point and continued until finished, the time being from two to three days. The organization of each gang was as follows: 8 men drawing spikes, 4 men throwing rails, 12 men spiking, 1 man distributing spikes, 2 men pushing handcars, 1 man carrying water, 1 man driving down spike stubs, 1 extra man. The equipment for each gang was as follows: 9 claw bars, 4 lining bars, 3 gages, 13 spike mauls, 1 water barrel, 2 water buckets, 1 standard gage dump car, 1 standard gage dump car, 1 standard gage hand car, 1 narrow gage dump car, 1 punch, 4 cleavers, 1 wrench, 2 rails 18 or 20 ft. long, and 1 pair of splice bars and bolts, to be placed about the middle of every curve of over 6°, in case rails were to be cut.

On standard gage track it is a general practice to widen the gage on curves, but the details of this practice vary considerably on different roads, as will be seen by Table No. 23. One factor in deciding as to the amount of widening required is the length of rigid wheelbase of the engines ordinarily running over the line. Some roads widen the gage on curves of 1°, while others only widen it on curves of over 10° or 20°. Where the widening is extreme, as on a sharp curve, an inside guard rail may be laid against the track rail to prevent driving wheels with blind tires from dropping off the track rail. The gage at frogs and switches should be normal, and not tight or slack in relation to the open track. If on a tangent, the gage at such places would be 4 ft. 8½ ins., and if on a curve the gage at the frog should be the same as on the rest of the curve. Some roads, however, widen the gage at these places, and the Atchison, Topeka & Santa Fe Ry. makes the gage 4 ft. 9 ins. at all turnouts, whether on curves or tangents. This widening extends through the switch and frog and narrows to 4 ft. 8½ ins. in a distance of 30 ft. beyond the frog. The gage of 4 ft. 9 ins. is also used for yard tracks from which many leads turn out. This question has also been discussed under the heading of "Frog Guard Rails," in Part 1. The widening should be effected by shifting the inner rail outward, keeping the outer rail at a uniform distance from the track centers throughout, and using this as the line rail.

TABLE NO. 23.—WIDENING GAGE ON CURVES (Standard Gage, 4 ft. 8½ ins.)

Curve.	Widening					
	N. Y. Cen.	Ph. & Rdg.	Que. Cen.	Lou. & Nash.	So. Pac.	A.T.& S. F.
Degs.	in.	in.	in.	in.	in.	in.
1....	..	..	..	..	..	1/8
2....	1/8	..	1/8	..	..	1/8
3....	1/8	..	1/8	..	..	1/4
4....	1/4	1/8	1/4	..	..	1/4
5....	1/4	1/8	1/4	1/4	..	1/4
6....	3/8	1/4	3/8	1/4	..	3/8
7....	3/8	1/4	..	1/2	1/8	3/8

Curve.	Widening				
	N. Y. Cen.	Ph.& Rdg.	Lo. & Nash.	South. Pac.	A.,T. & S.F.
Degs.	in.	in.	in.	in.	in.
8.......	1/2	3/8	1/2	1/8	3/8
9.......	1/2	3/8	1/2	1/4	1/2
10.......	5/8	1/2		1/4	1/2
11.......	..	1/2	1/4-in.*	3/8	1/2
12.......	..	..		..	5/8
15.......	..	..		..	3/4
20.......	..	..		..	1

* 1/4-in. for each additional 2½°.

Grades.

The maintenance work on grades may be increased very considerably if the traffic is heavy, owing to the increase in wear of rails resulting from

the use of sand in ascending and the application of the brakes in descending, and also to the general displacement and disturbance of the track, and the creeping of rails, all of which are aggravated on steep grades. For these reasons, as well as the increased cost in operating train service, it is economy to keep the grades down as much as possible in construction, especially if there is a heavy traffic probable. On the Erie Ry. great expense was incurred in order to keep the grades down to 1.14%, and many railways have either spent large sums in reducing grades or are operating at more or less disadvantage from heavy grades. On the other hand, for light traffic or temporary use, heavy grades may wisely be used to avoid the immediate construction of heavy permanent works, as in the case of surface lines in mountain districts to avoid tunnels on a low grade line, which may be built later. Some particulars of the grades used in switchbacks on main lines will be found in the chapter on "General Improvements."

When curves occur on heavy grades the grade should be so reduced that the combined train resistance due to grade and curve will not exceed that due to the maximum grade allowed on the tangent. This reduction is variously taken at 0.1 to 0.05% per degree, 0.04% being about sufficient on all curves. Thus, with a maximum grade of 2% on tangents, and a rate of compensation of 0.04% per degree, the maximum grade on a curve of 6° would be 1.76%. At or near stations and stopping places the rate of compensation should be nearly twice as great, or 0.06 to 0.08%. The amount of elevation lost by compensating the grade is found by multiplying the degree of central angle of the curve by the rate of compensation, and this elevation divided by the length of grade will give the rate by which the tangent máximum must be increased to introduce the compensation without a final loss in elevation. The change in grade may commence at the nearest even station, and not necessarily at the P. C. or P. T.

Vertical Curves on Grades.

Changes in grade exceeding 0.5% may be rounded off by vertical parabolic curves. The advantage of the use of vertical curves in relation to the operation of train service is discussed at some length in Wellington's "Economic Theory of Railway Location," and it is there pointed out that these advantages are of far greater importance at sags than at summits, the length for such curves being recommended as 200 ft. on each side of the vertex

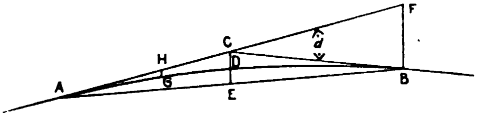


Fig. 203.—Vertical Curves for Connecting Railway Grades.

It is also pointed out, however, that with the universal adoption of an automatic close coupler much of the importance of these vertical curves would disappear. With trains having much slack in the couplings a rate of change of grade of 0.025 per station of 100 ft. would best fill the required conditions, but for ordinary service (especially after the introduction of improved couplers) 0.05 per station will be ample. The method of laying out these curves is given fully in Searles' "Field Engineering," and need not be given here, but Table No. 24, giving corrections for grade ele-

vations to be used where vertical curves are used on railways in rounding off the angle formed by the junction of two grade lines, may be of interest. It was prepared by Professor Nagle, and published in "Engineering News," New York, Nov. 26, 1896. It gives the vertical distance from grade line to curve at different points along the curve. The length of curve should be about 600 ft. at summits, and 800 to 1,200 ft. at sags. The curve employed is the usual parabola, chosen because of the ease with which any correction may be found when the correction at the vertex, or meeting point of grade lines, is known. Two properties of the parabola are utilized: 1,

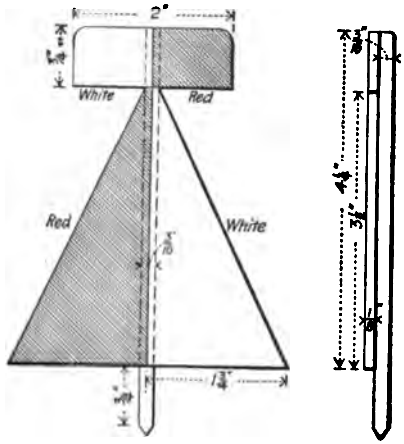


Fig. 203A.—Track Flag for Lining Curves. (See p. 291.)

that ordinates from tangent to curve vary as the square of the distance from the point of tangency; and, 2, that the curve bisects the vertical intercepted between the vertex and long chord joining the P. C. with the P. T.

In Fig. 203 H G ($=$T) is the correction at distance X from A; C D ($=$M) is the correction at the vertex, and 2 L is the length of the curve in stations; then the property first referred to gives the relation.

$$T = M \frac{x^2}{L^2}. \tag{1}$$

To find M, produce A C to F to meet a vertical through B, the end of curve. Call the algebraic difference of grades d, then will F B $=$ L d, and since C D $= \frac{1}{2}$ C E by the second property, M $= \frac{1}{4}$ F B, or

$$M = \tfrac{1}{4} L\,d. \tag{2}$$

The length of curve, 2 L, may be fixed by the circumstances of the case or may be found by assuming a certain rate of change of grade per station, the rate of change increasing with d. Call this rate of change R, then for L in stations

$$L = \frac{d}{2R}. \tag{3}$$

To find the correction at a point one station distant from the P. C. at A,

insert the value of d from (3) in (2), and the resulting value for M in (1), x being one station; the result is

$$T_1 = \frac{1}{2}\,\frac{L^2 R}{L^2} = \frac{1}{2} R. \qquad (4)$$

At two stations from A, $T_2 = 2$ R; at three stations, $T_3 = 4\frac{1}{2}$ R; at half a station, $T_{\frac{1}{2}} = \frac{1}{8}$ R, etc.

The table gives values of T for points 50 ft. apart for a few values of L and d. These corrections must be added when the algebraic difference of grades is minus, and subtracted when the algebraic difference is plus.

TABLE NO. 24.—CORRECTIONS FOR VERTICAL CURVES.

Algebraic difference of grades. %	Rate of change per station. ft.	Horizontal distance from vertex in feet. 0	50	100	150	200	250	300	350	400
		Vertical distance in feet.								
0.3	0.075	0.15	0.08	0.04	0.01	0	..	..	..	..
0.4	.1	.20	.11	.05	.01	0	..	..	..	..
0.5	.125	.25	.14	.06	.02	0	..	..	..	..
0.6	.15	.30	.17	.08	.02	0	..	..	..	..
0.7	.175	.35	.20	.09	.02	0	..	..	..	..
0.8	.20	.40	.23	.10	.03	0	..	..	..	..
0.9	.225	.45	.25	.11	.03	0	..	..	..	..
1.0	.25	.50	.28	.13	.03	0	..	..	..	..
1.1	0.1833	.83	.57	.37	.21	.09	.02	0	..	..
1.2	.20	.90	.63	.40	.23	.10	.03	0	..	..
1.3	.2167	.08	.68	.44	.24	.11	.03	0	..	..
1.4	.2333	1.05	.73	.47	.26	.12	.03	0	..	..
1.5	.25	1.13	.78	.50	.28	.13	.03	0	..	..
1.6	.2667	1.20	.83	.53	.30	.13	.03	0	..	..
1.7	.2833	1.28	.89	.57	.32	.14	.04	0	..	..
1.8	.30	1.35	.94	.60	.34	.15	.04	0	..	..
1.9	0.2375	1.90	1.46	1.07	.74	.48	.27	.12	.03	0
2.0	.25	2.00	1.53	1.13	.78	.50	.28	.13	.03	0
2.1	.2626	2.10	1.61	1.18	.82	.53	.30	.13	.03	0
2.2	.275	2.20	1.68	1.24	.86	.55	.31	.14	.03	0
2.3	.2875	2.30	1.76	1.29	.90	.58	.32	.14	.04	0
2.4	.3	2.40	1.84	1.35	.94	.60	.34	.15	.04	0
2.5	.3125	2.50	1.91	1.41	.97	.63	.35	.16	.04	0
2.6	.325	2.60	1.99	1.46	1.02	.65	.37	.16	.04	0

Curves.

A large proportion of the railway mileage is composed of curves, especially on lines where heavy curvature has been adopted through bad location or to reduce the cost of construction. The maintenance work is usually greater on curves than on tangents for the following reasons: 1, the tendency of the traffic to throw the track out of line by the pressure of the wheels against the outer rails (in spite of superelevation of rails); 2, the increased wear of rails by (a) the pressure of the wheel flanges, (b) the sliding of the wheels transversely, due to the fact that the axles are not parellel with the radius of the curve, and (c) the sliding of the wheels longitudinally, due to the fact that the outside wheel has to travel on a longer path than the inside wheel in the same time.

The curvature is not usually reckoned by the radius (except in the case of very sharp curves at yards, etc.), but by the number of degrees of central angle subtended by a chord of 100 ft. The radius of a 1° curve with a 100-ft. chord is 5,730 ft. (or more exactly, 5,729.65 ft.), and the radius on center line (R) or degree (D) of any curve may be obtained by the following formulas:

$$R = 5{,}730 \div D. \qquad D = 5{,}730 \div R.$$

Fig. 204 shows the various nomenclatures used in curve work. The "central angle" (A) is the angle contained within the radial lines to the extremities of the curve, or the P. C. (point of curve) and P. T. (point of tangent). The "degree of curve" (B) is the portion of the central angle which is contained within radial lines to a chord 100 ft. long on the curve. The "angle of intersection" (C) is the exterior angle at the intersection of the two tangents produced, and this angle is equal to the "central angle" (A). The "angle of deflection" (D) is the angle contained within the tangent produced and a 100-ft. chord on the curve. Taking X as the length of curve, in feet; Y as the degree of curve; and Z as the central angle, the relations may be obtained by the following formulas:

$$X = 100 \frac{Z}{Y} . \quad Y = 100 \frac{Z}{X} . \quad Z = \frac{YX}{100}$$

Table No. 25 affords a handy means of ascertaining the degree of a curve in the track (see "Lining"). It is based upon that arc of the outer rail which is cut off by a chord tangent to the gage side of the inner rail, the middle ordinate being the gage of the track. The length of the arc may be measured by rail lengths on a short curve, or by feet on a long curve. To find the degree of the curve, stand at a joint on the outer rail and sight across the gage side of the inner rail to the outer rail. Then count the rails between these points, or measure the chord A C, or arc A B C, Fig. 204, A, and the degree of curve will be found in the table.

TABLE NO. 25.—CURVE FUNCTIONS.

Degree of curve.	Radius of center line, ft.	No. of 30-ft. rails in A B C.	Length of arc A B C, ft.	Length chord A C, ft.	Central angle Deg.	Central angle Min.
1	5,730	15½	463.5	463.4	4	38
2	2,865	11	328.6	328.4	6	34
3	1,910	9	268.1	267.9	8	02
4	1,433	8	232.5	232.2	9	17
5	1,146	7	208.0	207.7	10	24
6	955.4	6⅓	190.0	189.7	11	22
7	819.0	5 5-6	175.8	175.5	12	16
8	716.8	5½	164.8	164.5	13	08
9	637.3	5 1-6	155.2	154.8	13	54
10	573.7	4 9-10	147.5	147.1	14	40
11	521.7	4⅔	140.6	140.1	15	22
12	478.3	4½	134.8	134.3	16	04
13	441.7	4 3-10	129.5	129.0	16	42
14	410.3	4 1-10	124.8	124.3	17	20
15	383.1	4	120.6	120.1	17	56
16	359.3	3 9-10	116.8	116.3	18	30
17	338.3	3 8-10	113.3	112.8	19	04
18	319.6	3 7-10	110.3	109.8	19	38
19	302.9	3 6-10	107.4	106.8	20	10
20	287.9	3 5-10	104.7	104.1	20	40

To set out a circular curve starting from a tangent, Fig. 205, the tangent approach is first carefully lined up and a stake (B) set at the P. C., and another (A) 100 ft. back on the tangent (both on center line of track). The tangent is then lined in for 100 ft. beyond the P. C., at (A) giving point (C). The 100-ft. tape or cord is then held by one end at (A) while its other end is moved inward from (C) for the distance given in Table No. 26 as the tangent deflection on a chord of 100 ft. for a curve of the required degree. This gives point (D) on the curve, and a stake is set at this point. The chord (A D) is then extended to (E), 100 ft. The tape being held at (D) its free end is moved inward from (E) for the distance given in the table as the curve de-

flection on a chord of 100 ft. for a curve of the required degree. This gives another point (F) on the curve. The curve deflection (E F), (G H) is always twice the tangent deflection, (C D), (L K). The points (H) and (J) on the curve are set out in the same way from (F) and (L). If the curve ends at (H), as shown, then from the point (L) the tape will be swung in for the distance previously used for the tangent deflection (C D), and this will give a point K on the tangent, 100 ft. from the P. T. at (H). Intermediate points on the curve may be set out by measuring the middle ordinate for each 100 ft. chord, as given by the table, thus marking the points (M), (N) (O), Fig. 205. The middle ordinate (M) of a 30-ft. rail, the quarter ordinates (R) of a 30-ft. rail, and the middle ordinate (S) of a rail of any other length (T) may be obtained by the following formulas:

$$M = 0.02 \times \text{Degree of Curve.} \quad R = M \times 0.75. \quad S = M \times \left(\frac{T}{30}\right)^2$$

Table No. 26 gives the tangent offset (C D, Fig. 205) for a tangent B C and chord B D, both 100 ft. long, and also the middle ordinate of a chord 100 ft. long, so that the table may be used in setting out curves by offsets or ordinates. In the former case it must be remembered that the curve offsets, E F, G H, etc., are double the tangent offset.

TABLE NO. 26.—CURVE OFFSETS AND ORDINATES.

Degree of curve, deg.	Degree of curve, min.	Tangent offset, ft.	Middle ordinate, ft.	Middle ordinate, ins.	Degree of curve, deg.	Degree of curve, min.	Tangent offset, ft.	Middle ordinate, ft.	Middle ordinate, ins.
1	0	0.873	0.218	2⅝	7	0	6.105	1.528	18⅜
1	30	1.309	0.327	..	7	30	6.540	1.637	..
2	0	1.745	0.436	5¼	8	0	6.976	1.746	21
2	30	2.181	0.545	..	8	30	7.411	1.855	..
3	0	2.618	0.654	8	9	0	7.846	1.965	23½
3	30	3.054	0.763	..	9	30	8.281	2.074	..
4	0	3.490	0.872	10½	10	0	8.716	2.183	26¼
4	30	3.926	0.982	..	10	30	9.150	2.293	..
5	0	4.362	1.091	13	11	0	9.585	2.402	29
5	30	4.798	1.200	..	12	0	10.453	2.620	31⅜
6	0	5.234	1.309	15¾	15	0	13.053	3.277	39⅜
6	30	5.669	1.418	..	20	0	17.365	4.374	52½

Transition curves should never be lined by eye alone, but by proper stakes. Where a circular curve starts directly from a tangent the foreman may (and always will) ease off the curve entrance to make an easier riding track. This is done by throwing the track in at the P. C., and though this necessarily sharpens the curve elsewhere, it is an advantage in giving an easy change from the tangent to the true curve.

Sharp curves exist on many main lines, having been introduced either from bad location or in order to keep down the grades and reduce the cost of construction. While there is little practical objection to the free use of curvature on a properly located line, many roads have spent large sums of money in taking out or flattening curves to improve the alinement, especially where there is heavy and fast traffic. The Mexican Ry. has numerous curves of 350 ft. and 325 ft. radius, and while building a difficult tunnel its main line traffic was handled successfully over reverse curves of 150 ft. radius, the traffic being light. Curves of 8° to 15° are used on many mountain lines. The Canadian Pacific Ry. has at one point along the Kicking Horse River, a long curve of 22° (nearly a semicircle); it was laid with a superelevation of 6 or 7 ins., but much grinding took place, and the rails are now level, laid to a gage of 4 ft. 10 ins. The passage of traffic over this curve has been so satisfactory that a proposed ex-

pensive tunnel (through running clay) to take out this curve has not been built. The train resistance due to curvature is in practice sometimes taken as ½-lb. per degree for each degree of curvature.

Very sharp curves are required in yards occasionally, at Y's or triangles, and particularly for sidings entering storehouses, grain elevators, factory yards, etc. A single car can be hauled round a curve of 40 ft. radius, as in entering a warehouse, etc., where room is limited and land is valuable. Where trains of two or more coupled cars are run, the radius may be 90 or 100 ft., though there may be occasional trouble from the corners of the cars striking each other, unless long coupling links or bars are used. It is not generally advisable to use four-wheel switch engines on curves of less than 75 ft. radius. The outer rails may be wide and flat to give a bearing to the wheel flanges of cars. On all such specially sharp curves care should be taken to have the curvature uniform and regular, the gage properly widened, rails braced, and guard rails properly set, and the maintenance properly attended to. Table No. 27 gives particulars of some of the sharpest curves on open track and in yards:

TABLE NO. 27.—SHARP CURVES ON STANDARD GAGE TRACK.

Railway.	Locality.	Radius, ft.	Sharpest curve. Deg.	Min.
N. Y., N. H. & Hartford	Springfield, Mass.	410	14	..
Lehigh & Susquehanna	Upper divisions	383	15	..
" " "	Stony Creek	320	18	..
" " "	Butler Branch	310	18	32
Baltimore & Ohio	Harpers Ferry (Md. side)	400	14	22
" " "	Harpers Ferry (Va. side)	300	19	10
" " "	Ilchester	375	15	20
" " "	Y for consol. locomotives	136	43	..
Erie & Wyoming Valley[1]	Dunmore, Pa.	310	18	30
Virginia Central	Over Rockfish Gap tunnel.	300	19	10
" "	Over Rockfish Gap tunnel.	238	24	15
Prov., Warren & Bristol[2]	Providence, R. I.	271 to 211	21° to 27°	
Chesapeake & Ohio	Cincinnati	187, 210, 231	30° 50′ to 25°	
Canadian Pacific[3]	Kicking Horse River	260	22	..
Pennsylvania	Centennial Exposition; 1876	300	19	10
Pitts., Ft. Wayne & Chicago	Pittsburg, Pa.	246	23	30
Canarsie & Rockaway	Brooklyn, N. Y.	173	33	15
Brooklyn, B. B. & Coney Isld.	Brooklyn, N. Y.	55 to 125	104° to 56°	
Manhattan Elevated	New York city	90, 100, 103½, 125.	63° " 56°	
New York Central	Grand Central Sta., N. Y.	320 to 400	Main tracks.	
" " "[4]	Grand Central Sta., N. Y.	75 and 80	Yard tracks.	
" " "	Center St., New York	50 to 60	105° to 96°	
Chic., Mil. & St. Paul	Minneapolis side track	125	47°	
C., C., C. & St. Louis	St. Louis, Mo.	206	28°	
" " " " " "[5]	Lafayette, Ind.	240	24°	
" " " " " "[6]	Cincinnati, O., yards	70	82°	
Pitts., Cin., Chic. & St. Louis[7]	Cincinnati, O., yards	50 and 52	Extend'g 90°	
U. S. Military Ry. (1861)	Petersburg, Va.	50	105°	
Lima & Oroya	Peru	395	14	32
Den. & Rio Grande (3 ft.)	Main track	...	24° and 33°	
" " " "	Quarry track	...	35° " 40°	
Mexican National (3 ft.)[8]	Manzanillo	144.3	40°	

1.—The Erie & Wyoming Valley Ry. has at Dunmore, Pa., a loop of 310 ft. radius, over which consolidation, mogul and eight-wheel engines run without difficulty, and often at considerable speed up to 20 miles per hour. The gage is 4 ft. 8½ ins., and the superelevation of outer rail is 6 ins. The rails are 67 lbs. per yd., and there is no guard rail.

2.—The Providence, Warren & Bristol Ry. has a nearly semicircular curve at Providence, R. I., beginning at 271 ft. and gradually reducing to 211 ft. radius, which is the radius for about 90°. Double truck engines are used, but eight-wheel engines were enabled to run by giving the front driving-wheels blind tires 7 ins. wide, while a third and fourth rail were laid on the inside of the curve for the blind tires to run on.

3.—This curve on the Canadian Pacific Ry. has been noted above.

4.—Three spur tracks to the freight warehouse of the Adams Express Co. on the east side of the Grand Central Station yard, New York, are of 75 and 80 ft. radius on the center lines, and they are found to be entirely satisfactory. The cars used are standard baggage cars, 50 ft. long. The engine used is one of the ordinary four-wheel yard switchers, with a four-wheel tender. The only alteration made to adapt this engine to these curves was to lengthen the drawbar between the engine and tender, so as to separate their end frame bars by a distance of 1 ft. 4 ins., which admits of their taking the curves with perfect ease. The tires are 5½ ins. wide, with a 4-in. tread, and the flanges are 1 in. high. The wheel gage is 4 ft. 5½ ins. back to back of tires, and the track gage is 4 ft. 9 ins., or ½ in. wider than standard. The driving wheels are 4 ft. 4 ins. diameter, with a wheel base of 8 ft. 0½ in.; and the tender wheels are 2 ft. 6 ins. diameter, with a wheel base of 7 ft. 6 ins.

5.—Main track curve opposite station, superelevation, 2½ ins. Gage widened ¾ in., guard rail space 4 ins., 4-in. plank spiked outside inner rail to take blind drivers.

6.—There are two curves of 70 ft. radius, around which cars pass easily, as well as a pony switching engine with a wheel base of 7 ft. 6 ins. The shacklebar between the engine and tender was slightly lengthened, and the feed hose transferred from the sides to the center line to prevent the corners from jamming and tearing the hose. Bar links with holes 12 ins. apart are used between the cars to spread them apart and keep the corners from striking. Two to four cars are usually handled. The gage is spread 1½ ins. on these curves.

7.—These two sidings turn out of the street connection railway into a beef storehouse, and have each an angle of 90°. A four-wheel engine with 7-ft. wheelbase has been used, but as the street rails get filled with dirt it is the practice to rope the cars in and out. Engines with six driving wheels work regularly over sidetrack curves of 80 and 100 ft. radius.

8.—This is a terminal loop curve covering an angle of 241° 51.4′. The rails are 40 lbs. per yd., on ties spaced 24 ins. c. to c., with braces on every fifth tie. There is a guard rail on the curve, and one rail for blind drivers on the inside of the outer running rail. The engines are moguls with a driving wheel base of 12 ft., and the trains range from four 30-ft. box cars of 10 tons capacity and three 42-ft. passenger cars to 20 box cars and 5 passenger cars. There is a descending grade of 1-10th of 1% in the direction of the traffic.

The New York elevated railways have very sharp curves on right angle turns from one street to another. The Sixth Ave. line turns out of South Fifth Ave. by a circular curve of 90 ft. and 109 ft. radius for the inner and outer tracks (112° 13′ and 104° 20′) with short reverse curves of 267.2 ft. and 304.65 ft. radius at each end extending 13° 58′ at one end and 10° 29′ at the other. At Coenties Slip the Third Ave. line makes a double right angle turn by reverse curves of 125 ft. radius between tracks (or about 48°), and 119 ft. radius of inner track. The first curve covers 92° 45′ and the second 119° 45′.

In regard to sharp curves, an item to be considered in questions of widening gage, guard rail space, minimum radius, etc., is the length of the lap of the wheel flange below the rail head, and this has been given as in Table No.

28, by Mr. E. A. Hill, M. Am. Soc. C. E., the flange depth being taken as $1\frac{1}{8}$ ins.:

TABLE NO. 28.—LAP OF WHEEL FLANGES.

Diameter of wheel.	Length of lap, ins.	Diameter of wheel.	Length of lap, ins.
30 to 34 ins.	12	54 to 60 ins.	16
35 " 40 "	13	61 " 68 "	17
41 " 46 "	14	69 " 76 "	18
47 " 53 "	15		

On curves sharper than 12° or 15° an iron guard rail should be laid inside the inner rail to prevent derailment, being so placed as to come into action only as the flange begins to tend to mount the outer rail. This requires a spacing of $3\frac{1}{2}$ to 4 ins. (see the Table of Standard Track, in Appendix I). For guard rails at frogs and crossings, a spacing of $1\frac{3}{4}$ ins. is correct, but this would be bad practice on ordinary curves, as it would relieve the flange from action and throw all the normal guiding upon the guard rail. It is only admissible to thus throw a curve guard rail into constant action on extremely sharp curves, such as the 90-ft. curves of the New York elevated railways, where the guard rails are kept well lubricated. On these lines the flangeway is $2\frac{1}{4}$ ins. at check rail on curves, and 2 ins. at frogs. On very sharp curves a guard rail is sometimes laid on the inside of the outer rail (leaving $1\frac{3}{4}$ ins. flangeway) and another one outside of the inner rail, and as close to it as possible. The object of these rails is to help support the blind or flangeless driving wheels of engines when they have a dangerously narrow bearing on the track rail on these curves. The gage should be widened on sharp curves, as already noted in this chapter, under "Gage." For setting out curves, the center stakes should be not more than 50 ft. apart, and may be 10, 25 or 30 ft. apart, according to the sharpness of the curve.

In tracklaying, as well as in location, it is often desirable to ascertain the divergence of a curve from its tangent, and this is given by the following formula, prepared by Mr. Muenscher:

$$X = 0.875\ N^2\ D.$$

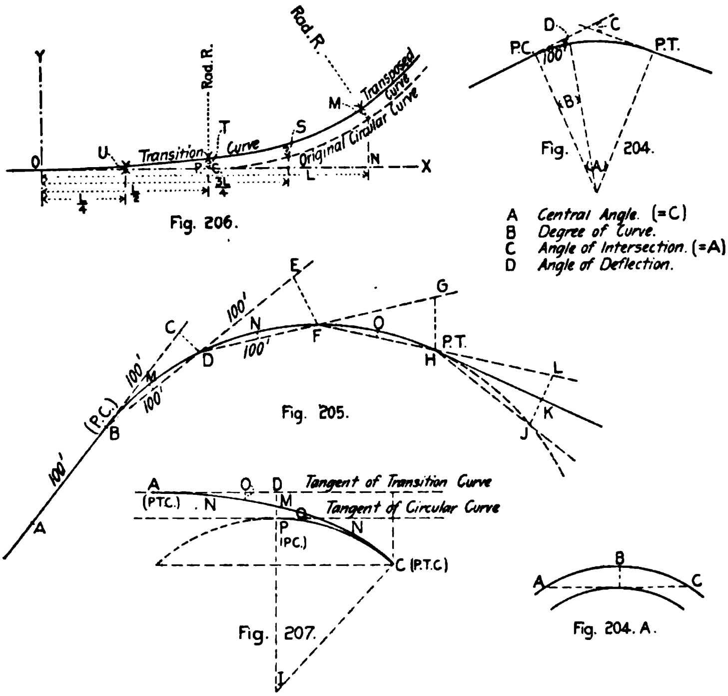
Here X is the offset, or distance of one end of a curve from a tangent passing through the other end; N is the length of the curve in chords of 100 ft.; and D is the degree of curvature. Thus the divergence of a curve of 6° from its tangent in a length of 500 ft., will be as follows:

$$0.875 \times 5^2 \times 6 = 131.25 \text{ ft.}$$

By making D equal to the difference of the degree of curvature of two curves of different radius, but having a common origin, X will be their divergence from each other at the end of N stations. In tracklaying, if we make X = the gage of track, and D = the degree of curvature of a turnout track (or corresponding to a given number of frog), N will be the lead of the main track. If X is half the gage, N will be the lead of the crotch frog, and if X is the throw of a stub switch, N will be the free length of the switch rail. The formula is sufficiently accurate for practical purposes, and is of great use in field work, with the aid of a table of actual tangents for a 1° curve. For example, in location, suppose a 5° curve to the right, 8 stations long, has been located, and its extremity falls 28 ft. too far to the right to throw the tangent on the best ground. Making X = 28, would give D = $\frac{1}{2}$°, showing that a 4° 30′ curve starting from the same

origin would pass through the required spot. Suppose that in the same case the new curve is to commence 200 ft. back of the first one; then the required divergence from the tangent will be $0.875 \times 8^2 \times 5 - 28 = 252$. Substituting this value for X and making $N = 5 \times 2$, gives $D = 2.88 = 2° 53'$.

In regard to rail wear on curves, the greatest wear is on the inner side of the head of the outer rail, which has to guide the flanges of the wheels. The corner and side of the rail head gradually wear to conform to the section of wheel fillet and flange, and the top of the head wears so as to give a slope upward from the inner corner. This wear becomes greater as the head wears to the shape of the wheel flange. The inner rail does not get cut away in the same manner, as the flanges run from instead of



Curve Diagrams.

towards it, but the longitudinal and lateral slipping of the inner wheels, the greater weight and the lateral force of the weight upon this rail wear the head down and deform it, often forcing the metal out in a lip beyond the original line of the side of the head. The pressure against the outer rail, and the weight on the inner rail, with its angular inclination, due to the inclination of the engine by the superelevation, tends to overturn the rail by forcing the outer edge of the flange into the ties and drawing the inner spikes. This has been usually resisted by rail braces on the outside of the rail, but the use of metal tie-plates has been found even more efficient, as they prevent the cutting of the wood of the tie. The work of maintaining the gage on curves may be considerably reduced by the use of tie-plates and rail braces, or on heavy curves by the use of bridle-rods

or tie-bars holding the base of the rails like switch rods, there being from two to four bars to a rail length. In European practice, tie-rods through the rail webs are sometimes used on extreme curves.

Transition Curves.

It is difficult to make an easy riding track where circular curves spring directly from the tangents. The cars will pass as easily and smoothly round a well-laid curve as along an equally well-laid tangent, but there is an unpleasant lurching motion at the entrance and end of each curve, due to the sudden change of direction from rectilinear to circular motion. The effect of this lurching is shown by the increased wear of the rails at this point, indicating that a lateral force is exerted, which has to be resisted by the rails. In very many cases some attempt is made to remedy this by some form of easement or transition curve. Even if this is not done, the lurching will soon be materially lessened by the traffic slightly shifting the track to the position giving it the easiest path (which is the worst way of attaining a very desirable end), or by the common practice of the track foremen in easing off the ends of the curve by the eye. If transition curves are not used, the foremen will almost invariably have the ends of the curve thrown inward by the lining bars, so that the curve practically extends 100 ft. or so onto the tangent, the curve being flattened at this point, and consequently sharpened a little beyond the located point of the curve, where however, the lurch or swing is less felt. The curve thus altered rides very much easier than the true circular curve springing directly from the tangent, and it is probable that there are very few curves maintained actually in this latter condition, even on roads where transition curves are not approved. The New York Central Ry. and Pennsylvania Ry. do not use transition curves, but for curves of 4° and over an easier curve is introduce at each end, and compounded with the main curve.

The best way to lay out the curves (especially for high speed lines) is to locate or relocate the line with easement or transition curves connecting the main circular curve with the tangents. These should be permanently monumented, marked (preferably by stakes 25 or 30 ft. apart) and the trackmen should be required to maintain the alinement as set, and not allowed to modify it to suit their individual ideas. The rail wear and the maintenance work for alinement at curves will be much less on a track thus located, and the trackmen soon come to realize this in its relation to their work. Transition curves are used either on all curves, or on all over 3° or 4°, and the length may be from 50 to 300 ft., according to the degree of main curve and the local conditions. On old roadbeds, where no great change in position of the track is practicable, transition curves can still be fitted by slightly sharpening the degree and radius of the main curve, and moving the middle of the curve a few inches out and the ends a few inches inwards. Curves thus treated are longer than simple curves, so that in relocation, where reverse curves separated by short tangents occur, the tangents will be still further shortened. Absolute reverse curves cannot be so relocated without increasing the curvatures to get in the necessary length for the transition betwen them, but such curves so transitioned are very much less objectionable than circular reverse curves of easier curvature and with short connecting tangents.

The following method of setting out transition curves, which is specially

adapted to work on existing track, is given by Mr. David Molitor, and has been used on the German government railways and the Illinois Central Ry. The circular curve is staked out on the ground in the usual manner, stakes being driven at the P. C., and on the tangent at distances $\frac{L}{4}$ and $\frac{L}{2}$, Fig. 206, and also on the curve at the same distances from the P. C., the distance L being the length of transition curve as given in Table No. 29. Having these five stakes, offsets are measured towards the center of the curve as given in the table, and stakes set at the ends of these offsets are the track centers. The position of the circular curve between its two transition curves is given by the constant offset M. The figures given in Table No. 29 are sufficient for all practical purposes. In the equation for the curve, L R is a constant, 173,800, which is found to give good results without excessive values for M. The length of transition curve is then,

$$L = \frac{173{,}800}{R}$$

For points between O and the P. C. the ordinate U from the tangent is given by formula A, and for points between the P. C. and N the offset S from the circular curve is given by formula B.

$$\text{(A)}\quad U = \frac{X^3}{6\,L\,R} = \frac{X^3}{1{,}042{,}800} \qquad \text{(B)}\quad S = \frac{X^3}{6\,L\,R} - \frac{(X-L)^2}{2\,R}$$

TABLE NO. 29.—OFFSETS FOR STAKING OUT TRANSITION CURVES FROM CIRCULAR CURVES.

Degrees of curve, degs.	mins.	Radius, R ft.	L ft.	Offsets. $X=\frac{L}{4}$ U ft.	$X=\frac{L}{2}$ T ft.	$X=\frac{3L}{4}$ S ft.	$X=L$ M ft.
2	00	2,864.9	60.7	0.003	0.027	0.051	0.054
2	15	2,546.6	68.3	0.004	0.038	0.071	0.076
2	30	2,292.0	75.9	0.006	0.052	0.098	0.105
2	45	2,083.7	83.4	0.008	0.069	0.130	0.139
3	00	1,910.1	91.0	0.011	0.090	0.176	0.181
3	15	1,763.2	98.6	0.014	0.115	0.216	0.230
3	30	1,637.3	106.2	0.018	0.143	0.269	0.287
3	45	1,528.2	113.7	0.022	0.176	0.330	0.352
4	00	1,432.7	121.3	0.027	0.214	0.401	0.428
4	15	1,348.5	128.8	0.032	0.257	0.481	0.513
4	30	1,273.6	136.4	0.038	0.304	0.570	0.608
4	45	1,206.6	144.0	0.045	0.358	0.671	0.716
5	00	1,146.3	151.7	0.052	0.418	0.783	0.836
5	15	1,091.7	159.3	0.060	0.484	0.907	0.968
5	30	1,042.1	166.8	0.069	0.556	1.042	1.112
5	45	996.9	174.4	0.079	0.636	1.191	1.271
6	00	955.4	181.9	0.090	0.722	1.352	1.443

Parabolic curves are sometimes used instead of circular curves, but are of comparatively little effect, as far as "transitioning" is concerned, and the same may be said of the plan of throwing in the whole of the curve, except about 100 ft. at each end, connecting with the tangents. The best results are undoubtedly obtained with circular curves, properly transitioned, and in the late A. M. Wellington's "Economic Theory of Railway Location" the case is concisely stated as follows: "What is wanted is (1) to ease off the curve by a rapidly changing radius for a short distance at the ends—a transition curve; and (2) to leave the great body of the curve of

uniform radius." With such a curve the work of the trackmen will be considerably reduced, and there will also be less wear of wheel flanges and rails, and rolling stock. The easement, or transition, may be effected in three ways: 1, By a compound curve, whose ends are of greater radius than the central arc; 2, by compounding short circular arcs of gradually increasing radius, until the radius of the main central arc or curve is reached; or, 3, by a spiral curve. The Searles "spiral" (which is of the second class, with curves of equal length), and the Holbrook spiral, are extensively used, as well as modifications of various "spiral" systems introduced by engineers on different roads. A majority of railways employ one or other of these systems in the alinement of track, although there are some notable exceptions, the objections usually urged by these latter being as follows: 1, The benefits are largely theoretical; 2, the practical effects are obviated by the variable velocity of the traffic; 3, the curves are more difficult to lay out and to maintain in alinement. The first objection can hardly be sustained in the face of extensive experience as to the practical advantages derived, and which are worth much more than they cost. As to the second, while it is true that the easement cannot be made to fit the variations of train velocity, it can be made to fit the prevailing velocity; this same objection would apply to the superelevation on curves; but no engineer would propose to dispense with superelevation. As to the third objection, the computation and field work of location are but little more difficult than for circular curves without easement, the extra trouble being mainly in the plotting, and the maintenance of alinement is no more difficult if the curve is properly and permanently marked and the foreman is required to line by the engineer's stakes, and not by his eye. The details of plotting and location may be found in various field books and in works on the transition curves, and would be out of place here.

Mr. Wellington (in the beginning of the field book which he never completed) pointed out that, if to decrease the evil due to the connections at curves, we connect the same tangents and tangent points by parabolic instead of by circular arcs, we shall obtain curves which are of a longer radius at the P. C. and P. T. than the circular arc, but ordinarily only slightly longer. Thus the evils of the transition from tangent to curve and curve to tangent are only slightly alleviated, and there is the disadvantage that the curve is correspondingly sharpened in the center. While in no case is the amelioration of conditions as to radii considerable, a new, unfavorable effect is created; as the degree of a parabolic curve is constantly changing, and the change is very slow, the angle of the axis of the trucks to the axis of the car is likewise constantly changing, but with extreme slowness. Under these conditions the coefficient of friction between the center plates becomes a maximum, and the flange pressure and danger of the center plates binding and causing derailment are both materially increased. With the parabola, it is true, unlike the circle, it is unnecessary to have the tangents equal, and if unequal tangents are used, we shall at one end of the curve ameliorate still more the transition from tangent to curve, but at the expense of introducing less favorable conditions at the other end. On the whole, the parabola is under no conditions a desirable railway curve, as compared with a circle, even if it were more easy instead of more difficult to lay out. The best transition curve is that on the principle of the cubic parabola, being a short curve of varying radius,

which is interpolated between the circular curve and its tangent in order to make the passage from the one to the other less abrupt. It must be such that, starting with an infinite radius (or D = 0) at the P. C. (A), it will have a degree at every point in direct proportion to the distance from the P. C., until, at the P. C. C., where it connects with and becomes tangent to the main curve, it is of the same degree as that curve. Such a curve approximates closely to that of the cubic parabola, and with it the curvature and superelevation commence at the same point, the curve commencing easily, and its degree increasing gradually and uniformly, and yet quickly, until at some point it attains the degree of the main curve, the maximum superelevation being attained at the same point. The main circular curve is then continued until, near its end, it is again run out by a transition curve of decreasing degree into the tangent. The centrifugal force will thus be created gradually, and be exactly balanced at every point by a gradually increasing centripetal force from the superelevation, if the latter is precisely adapted to the speed; or, if not, the aggregate will be less and gradually created. The center plates of the trucks will move through the necessary angle quickly, and then remain unchanged until the curve is left. The use of the transition curve throws the curve out on the tangent, or makes it longer, which is what the practical trackman does by rule of thumb. The curve should be permanently staked and marked, and the foreman required to maintain it as laid out by the engineer. The marking may be by monuments of stone or pieces of old rail at the beginning, center and end of the transition curve, with oak stakes or old splice bars placed 30 ft. or 50 ft. apart, and 5 ft. on each side of the center. The length of transition curve varies, some roads specify 30, 50, 60 or 100 ft. per degree of curve, while others specify a uniform length of 150 to 300 ft., and the Southern Pacific Ry. makes them as long as practicable, but always maintaining at least 60 ft. of the central arc. The transition should be used for curves over 2°, the limit of different roads varying from 1° to 4°. A proper system of transition curves has the practical advantage of greatly simplifying the field work of connecting, adjusting and readjusting lines, while not adding sensibly to the time required for the first continuous location.

As a rule, the text-books make this too much of a mathematical ideality, with hair-splitting precision, so that beginners do not realize its importance and get to imagine that its value is purely theoretical, and not to be considered in the field. The curve may be laid out by deflection angles or by offsets, but as the differences of curvature are in most cases comparatively small, and the transit work, if rigorously done, becomes more complex, the offset method is particularly suitable. In all ordinary cases, for moderate length and offsets, the curve is sensibly a parabola, and always sensibly bisects the total offset. The offsets to the curve from the tangent and the circular curve are sensibly equal at equal distances from the extremity of the curve, and the offsets at the quarter points are always sensibly 1-16 of the total offset, or almost imperceptible, so that for grading purposes the curve is rarely more than half as long in fact as it is in theory. The track centers as well as grading centers may be laid out by offsets alone in all ordinary cases, with sensibly perfect accuracy. In general, when circumstances permit, the best way for determining a transition curve is to assume a length, and let the offset at the P. C. come where it will, but in many cases this is impossible or inexpedient, and the practical case is

that the offset F is given a fixed length, and a curve must be put in to fit it. The offsets should vary approximately as the cube of the degree of curvature of the main curve, and while differences in speed may properly be considered in selecting particular transition curves, that does not prevent the law from being as stated if it is desired to use curves changing in degree by a given quantity in a given distance. The minimum length of offset for a 2° curve, or any other transition curve, should be as large as can be conveniently obtained up to a foot or more, provided high speeds are expected. If they are not expected, or if there are many other much sharper curves, a 2° curve may, without sensible harm, be left without transition curves. In any case, it is waste of time to bother with offsets less than 0.1 in. (or even so small), as, within a year after the track is laid, it will almost certainly, under the trackmen's attention, vary more than that, often four or five times as much. In the application to compound curves, the transition curve to connect two curves, D° and $D^{1\circ}$, is practically identical (as to length and offsets) with one connecting a tangent with a curve whose degree is equal to the difference between the degrees of the two curves $(D^1 - D)^\circ$. The conclusions presented by Mr. Wellington in regard to this curve were as follows:

1.—The transition curve will deflect exteriorly from the given main curve, because the rate of curvature becomes continuously less.

2.—It will terminate in a tangent parallel to the given tangent, because the same central angle is consumed.

3.—The offset D P (= O), Fig. 207, bisects the transition curve A C in M.

4.—The transition curve A C bisects the offset O in M.

5.—At any intermediate points, O O^1, at equal distances from the corresponding P. T. C.'s, or from the middle point M, the offsets to the transition curve from the tangent, or from the main curve produced, are equal.

6.—The average degree of curvature between the P. T. C. at A and any two intermediate points, O and O^1, varies directly as the distances to these points from the P. T. C.

7.—The square offsets, O or O^1, from the tangent or the main curve produced, vary as the cube of the distance from the P. T. C.

8.—Any offset, O, may be used with any curve to connect the main curve with the tangent, and the length of the curve only will vary, varying as the square root of half the length of the transition curve.

9.—The half length (n) of the curve (A M or M C) equals the central angle I divided by the degree of the main curve.

Superelevation on Curves.

On tangents, it is important that the heads of both rails should be kept at the same level, or in the same horizontal plane, so as to insure easy and steady riding of the cars. On a curve, however, the centrifugal force of a moving train causes the train to tend to continue on its direct course in a straight line, thus throwing a severe and dangerous pressure of the wheel flanges against the outer rails. To reduce this, the outer rail is elevated above the lower one, and this causes the train to tend to run towards the center of the curve. The amount of this superelevation depends upon the degree of the curve and the speed of trains. The centripetal force may be made theoretically to exactly balance the centrifugal force, but in practice it is difficult to get universally satisfactory results since the important

factor of speed is so varying. Fast and slow trains travel over the same tracks, so that it is impossible to exactly adjust the actual elevaton to theoretical conditions, but a mean, or compromise, elevation must be adopted, taking into consideration the proportion of fast and slow trains. Some roads adopt but one fixed rate of elevation, while others adopt varying rates to suit varying speeds on different parts of their lines. The Southern Pacific Ry. gives the trackmen two elevation tables: One of these is to be used for main lines, and is calculated for a speed of 36 miles per hour; the other is for branch lines, and is calculated for 25 miles per hour. On most roads the maintenance of way department issues a table of curve elevations for different curves and speeds, and the roadmasters and foremen use such elevation as is required by the special conditions at individual curves, for practical considerations of traffic, location and speed very generally necessitate some modification of the theoretical elevation.

The centrifugal force (C) of a moving train is calculated by the following formula:

$$C = \frac{\text{Weight of train (tons)} \times \text{square of velocity (feet per second)}}{32.2 \times \text{radius of curve (feet)}}$$

The superelevation (E) to counteract this lateral force, is sometimes taken as 1-10 of the square root of the degree of the curve, giving the elevation in decimals of a foot. It is more usually calculated, however, by one of the following formulas:

$$E = \frac{\text{Gage (or distance c. to c. of rails) in ins.} \times \text{sq. of velocity in ft. per sec.}}{32.2 \times \text{radius of curve, in feet.}}$$

$$E = \frac{\text{Square of velocity, in miles per hour} \times \text{distance c. to c. of rails, in ft.}}{1.25 \times \text{radius of curve, in feet.}}$$

$$E = \frac{\text{Chord}^2}{\text{Radius} \times 8.}$$

The exact elevation of each individual curve may be made the subject of investigation. If the rule of the road or the practice of the enginemen is to reduce the speed on sharp curves, then such curves will require a proportionately less elevation than easier curves over which trains run at normal speed. It is, of course, useless to carry out the tables to very high figures, for the elevation cannot be carried beyond certain limits, while on very sharp curves trains should be required to reduce speed for considerations of safety, and a less elevation may then be introduced. The curve resistance in itself is also an element in reducing the speed on the curve. The elevation should, in general, be calculated for passenger train speeds, so as to insure easy riding, unless that elevation will be such as to interfere with slow freight trains. The maximum amount of elevation allowed should be 6 ins. (or exceptionally 7 ins.).

The maximum should, however, rarely be used, as it is too high for heavy freight trains moving at moderate speed, while fast trains usually slow down for curves on which such elevation might be required. In fact, if a road has many very sharp curves and operates a high speed traffic, it may be economy to change the alinement, and this point is fully discussed in Wellington's "Economic Theory of Railway Location," (Chapters VIII.,

XVIII. and XIX). If the elevation is too high for slow speeds, the weight on the outer rail is reduced, which makes it more easy for the wheel flange to mount the rail, and also introduces the liability of getting heavy trains stalled on the curve owing to the severe flange pressure and weight on the inner wheels. There is also a tendency of the ties to slide inwards in the ballast when inclined at a steep angle, which adds to the difficulty of maintaining good line under such conditions. In determining the elevation for a mixed traffic of various speeds, it is best to give greater consideration to the fast than to the slow trains, unless the latter are very numerous and very heavy. Whatever amount of elevation is decided upon, this amount should be maintained uniformly around the curve, as irregularity in this respect seriously affects the riding of the cars, and may introduce an element of danger. For this reason, among others, foremen should frequently test the elevations of their curves.

Foremen must exercise good judgment in giving the elevation according to the location of the curve, the degree of curve, speed, and local conditions which regulate the traffic. Thus, a 6° curve at the top of a grade should have less elevation than a 6° curve at the foot of a grade, and on double track the track on which trains run against the grade should have less elevation than that for trains running with the grade, as the former will have a slower speed. On sharp curves, near stations, crossings, etc., where trains always stop, but little elevation is required, as the speed is slow, and the same applies to similar curves near the summit of grades. It is not uncommon, however, to find excessive elevation for such locations, calculated, perhaps, for speeds of 30 to 40 miles per hour. Such excessive elevation may even stall a heavy slow train on account of the great weight thrown on the inner rail, especially if the grade is not compensated for curvature. On single track, a curve in a sag of grades may have the elevation increased. The Baltimore & Ohio Ry. gives two rules, one applying to single track, with trains in both directions; the other applying to double track on descending and light ascending grades. Curves of 10° should be avoided wherever possible on main tracks. If such curves are used, trains should be required to slow down, a "slow" board being set up some distance from the curve. In yards and on sidetracks half the usual elevation may be given.

Sometimes the degree of curve and the proper elevation are marked on a stake driven at each end of the curve (or at the beginning of the curve on double track), or stakes may be set to the required elevation, that is, 0 at the beginning of the curves and the maximum elevation at the point where this maximum is reached. The Buffalo, Rochester & Pittsburg Ry. gives this information on a sign spiked to a telegraph pole, as noted under "Track Signs." The methods of obtaining the proper elevation are described under "Track Tools" (Level Board), and "Surfacing." Where the degree of curve is not known, the elevation may be ascertained by taking a string 50 ft. or 62 ft. long, holding the ends to the gage line of the rail, and measuring the ordinate from the center knot to the rail, which will be the required amount. The Southern Pacific Ry. specifies the middle ordinate of a string 64 ft. long on main track (based on 36 miles per hour), and 44 ft. long on branch lines (based on 25 miles per hour). The length of string giving the ordinate and elevation suitable for different speeds is obtained by multiplying the speed in miles per hour by 1.587. In using the

string, measurements should be taken at different points, so that any specially sharp or flat places in the curve (which should be corrected when discovered) do not mislead in setting the elevation. The number of inches in the middle ordinate of a string 43 ft. long, is equal to half the number of degrees in the curve.

Table No. 30 shows the practice of different roads, and shows also the limit of speed for each curve:

TABLE NO. 30.—SUPERELEVATION ON CURVES.

Deg. of curve.	N. Y., N. H. & H. R.R., m. p. h., 40	50	Que. Cen.	N. Y. Central.	[1]A., T. & S.F.	So. Pac. m. p. h., 36	25	Balt. & Ohio. A[2]	B[3]	Louis. & Nash.[4] 25	30	35	40	45	Ill. Central. 30	40	50	60
½..	¾	1	..	⅝	..	½	¼	5-16	½	..	..	..	..	..	..	..	..	..
1 ..	1½	1¾	1	11-16	¾	1	½	⅝	1 1-16	½	⅝	⅞	1⅛	1⅜	½	1	1½	2
1½..	2	2¼	..	1 3-16	..	1½	⅝	1	1 7-16	..	..	..	..	..	..	..	..	..
2 ..	2⅜	2¾	1¾	1⅝	1½	2	⅞	1 5-16	2⅛	⅞	1¼	1¾	2¼	2¾	1	2	2⅞	3¾
2½..	2⅞	3¼	..	2	..	2½	1	1⅝	2⅝	..	..	..	..	..	..	..	..	..
3 ..	3⅛	3⅝	2½	2 7-16	2¼	3	1¼	2	3⅛	1¼	1⅞	2½	3¼	4¼	1½	2⅞	4⅛	5¼
3½..	3⅝	4	..	2 13-16	..	3½	1½	2¼	3 11-16	..	..	..	..	..	..	..	..	..
4 ..	4	4½	3¼	3¼	3	4	1¾	2½	4 3-16	1¾	2½	3⅜	4⅜	5½	2	3¾	5¼	6½
4½..	..	..	..	3⅝	..	4½	1⅞	2¾	4¾	..	..	..	..	..	..	..	..	..
5....	4⅞	5⅜	4	4	3¾	5	2⅛	3	5	2⅛	3⅛	4¼	5½	..	2½	4½	6¼	..
6....	5⅝	6⅛	4¾	4 13-16	4½	6	2⅝	3½	5½	2⅝	3¾	5	6	..	3	5¼	..	..
7....	6½	7	..	5⅝	5¼	6	3	4¼	6	3	4¼	5⅞	..	..	3½	6	..	..
8....	7⅜	7⅞	..	6 7-16	5¼	6	3½	4¾	6½	3½	4⅞	..	..	..	4	..	..	..
9....	..	..	..	..	5¼	..	..	5¼	7	3⅞	5½	..	..	..	4½	..	..	..
10....	..	..	..	..	5¼	..	..	5¾	7½	4¼	6	..	..	..	5	..	..	..
11....	..	..	..	..	..	..	..	..	..	4⅝	..	..	..	..	5½	..	..	..
12....	..	..	..	..	..	..	..	..	..	5⅞	..	..	..	..	6	..	..	..

[1] Maximum. A[2] For curves on steep ascending grades on double track; 40 miles per hour. B[3] For curves on single track, or descending and light ascending grades on double track; 40 miles per hour to 5° curves; 35 miles per hour on sharper curves. Maximum, 8½ ins. [4] Maximum, 6 ins.

As the superelevation cannot be attained abruptly, it must be carried a certain distance beyond the curve. If the superelevation does not begin until the P. C. is reached the centrifugal force there suddenly generated is entirely unbalanced, with the result of giving a dangerous and destructive lurch to the car and a disagreeable lurch to the body of the passenger. If the superelevation is equally divided between certain distances on each side of the P. C. an unbalanced centripetal force is first created, to which the car and passengers adjust themselves, and this at the P. C. is instantly changed into an equally great centrifugal force, with results again disagreeable to the passenger, and productive of almost as much wear and tear, since the sudden twist of the track remains unaltered, and the sudden reversal of strain from — ½ to + ½ of the centrifugal force has but slightly less injurious effect than the sudden application of the whole centrifugal force where none previously existed. The best and most common practice is to maintain the elevation uniformly over the whole length of the curve, from P. C to P. T., and then to run it out on the tangent at the rate of 50 ft. in length for each degree of curvature, or ⅛ in. reduction of elevation in each rail length. Some roads, however, maintain a uniform run-off, as on the Atchison, Topeka & Santa Fe Ry., where the length is 120 ft., but this gives too steep a grade on sharp curves. When one rail is thus elevated on the tangent, the wheels will tend to run towards the high rail, and they are thus put in the best position for taking the curve. These remarks apply to circular curves, but where transition curves are used the run-out should coincide with the transition curve, so that the elevation conforms to the

radius at every point, thus getting the best possible results in every way, and for such curves a diagram of the elevation should be given to the foreman. On compound curves, the sharper curve should have the full elevation on its entire length, running out on the flatter curve to the elevation of the latter. On reverse curves, or curves with very short tangents between them, the elevation must be made gradually on the curves, commencing at the middle of the short tangent in the latter case.

The high rail should be the line rail, and this rail is usually raised to the required elevation, although on some roads the inner and outer rail are respectively lowered and raised by half the amount of superelevation, for the purpose of maintaining the center of gravity of the train uniform on curve and tangent.

Where curves occur on bridges and trestles, special methods are required for putting in the superelevation. On the New York Elevated Ry. the outer rail is raised by blocks 3½ ins. thick for all curves, which is found to be approximately correct. A greater elevation was at first used on curves of 90 ft. and 125 ft. radius, but this was reduced to 3½ ins. when the rails were relaid. The higher speed on the easier curves compensates to some extent for the uniform superelevation, while the use of only one thickness of block enables these blocks to be cut and stored for seasoning. The superelevation is run out from the P. C. and P. T. on the tangent for a distance of 30 ft. on 90-ft. curves to 50 ft. for 350 ft. curves. Several methods of elevating rails on bridges and trestles are given in the report for 1893, of the American Association of Superintendents of Bridges and Buildings:

1. Shimming on Ties.—A long shim carrying the outer rail and guard rail is spiked to the tie, but with any considerable elevation the rails get badly worn, as they are vertical, and the heads are not in the same plane. The shims are also liable to rot and to be broken in case of accident.

2. Taper Ties.—For moderate curves on structures where the ties are carried by stringers, the ties may be cut to a taper, the minimum thickness under the rail being 5 ins. With plate girders where the ties have to be cut out for the cover plates, they would be very weak on the thinner end, while a 14 ft. tie on a 6° curve would have to be 14 ins. thick at the larger end. Such ties are expensive, and must be kept in stock, each curve requiring ties of different thickness. As a matter of fact, comparatively few mills can saw ties to tapered dimensions.

3. Blocking under Ties.—The most general practice is to use ordinary ties and block them up to the required elevation by blocks on the stringers.

4. Cushion Ties.—These are made the full width of the ordinary ties and are laid upon them. They taper from a thickness of 3 ins. at the small end. They tend to cause decay of the tie and cushion tie by holding water between them, and, being thin, are liable to warp and to be split by the spike.

5. Cushion Caps.—On trestles tapered caps may be bolted to the main caps, boxed out 1 in. to 2 ins. for the stringers, but the boxing holds water. and water also gets between the cap and the cushion.

6. Corbels.—If the trestle is built with corbels, those on the outer side of the curve may be higher or thicker than the others, so as to raise the stringers.

7. Inclined Trestle.—The mudsills may be inclined to the proper degree

of elevation, so that the framing of the bents will not be affected, or the outer posts may be of increased length, keeping the mudsills level. The main objection is, that with slow trains, the weight on the inner rail would tend to throw most of the weight on the inner posts, so that only the sway bracing would resist the racking of the bent, which, with considerable elevation and a high trestle, would be very great. This might be prevented by increasing the batter of the inner posts, but such special construction of bents is undesirable. With a pile trestle, the piles may be cut off at the proper height for framing the caps at the required elevation.

8. Deck Plate Girders.—The outside girder may be raised by blocking, thus giving the proper inclination to the ties, but with trains slower than the speed for which the elevation is calculated, the load would not pass through the axis of the bridge, and would subject the girder to strains not provided for in the construction. A longitudinal timber may be bolted to the top chord of the outer girder, or blocks with inclined top faces may be placed on one or both chords, the latter being the better plan. In rare cases the outer girder is made higher, but this is not an advisable plan, apart from the extra trouble in manufacture for each structure, the cutting away of the ties for cover plates weakens them. With truss bridges, however, the outer floor stringer may well be raised, there being no long cover plates, so that the ties are boxed out uniformly.

9. Solid Floors.—The elevation may be made in the rail bearings if the floor is unballasted, or by inclining the ties in the ballast, if the ordinary roadbed is carried across the bridge.

CHAPTER 19.—TRACK INSPECTION AND THE PREMIUM SYSTEM.

The track is usually inspected daily by the trackwalkers, or by a man sent over the section on a velocipede, and the section foremen and supervisors have to make frequent examinations, not only in detail, but of the general condition of the track and roadway. This examination should be made on foot or from a handcar, but also occasionally from the engine or the rear car of a train, these latter methods giving a broader general view of the work and enabling the foreman to test the riding qualities of his track. The roadmasters and engineers should also make general inspections of the divisions under their charge.

On most roads of importance, especially where the premium system is in force, a general inspection is made once a year, of both the track and the property generally, record being kept of the condition of each section, station, etc., year by year. This inspection is usually made in the autumn. In general a special car is used, having the floor sloping up from the rear and fitted with seats, while the end is either open, or closed by large glass windows extending to the floor. This car is pushed ahead of an engine at the rate of 10 to 15 miles per hour, stopping at the end of each section, and the officials mark, on cards provided for the purpose, their rating of the condition of each section. The division roadmasters, section foremen, etc., do not mark their own divisions and sections. The markings of the cards,

are then figured up and prizes awarded according to the averages. In some cases the marking or judging is done by the roadmasters, engineers, division superintendents, etc., and where this practice prevails, the section foremen should be taken over the road after the awards have been made, so that they can see each other's sections. On the Boston & Albany Ry. there are five prizes for division roadmasters, and five (of $50 each) for section foremen, awarded on the following points: 1, alinement and surface; 2, joints and spiking; 3, switches and frogs; 4, ballast and ties; 5, ditches and general neatness and cleanliness of roadway. The highest rating under each head is 10, which would mean perfection, and the inspectors mark 2, 4, 5, etc., under each, according to their opinions. Some roads adopt the method of making the section foremen the judges, each foreman marking on every section but his own, considering this better than to appoint judges from among the roadmasters and division superintendents. The annual inspection is thus made to powerfully educate and arouse the spirit of the foremen, and induces a sharp rivalry. Each man becomes more critical of his own division, and in passing over the divisions he notes certain good and bad points, so that the system tends to make the general practice better and more uniform. It may be said here that from every point of view it pays to take the foremen over the road together once a year, even if no prizes are given, as it gives them more interest in and knowledge of their work, while an incentive to good work, in the shape of a prize, is a good thing. It is well also, to have a "Premium Section," sign board erected on the section tool house or elsewhere on the section, as the laborers themselves then feel that they are getting some recognition and will work hard to prevent any other section from winning away the premium sign. They will naturally take more pride in their work if it is thus publicly recognized, and the best plans for the premium system are those which make the men participators in the prizes.

On the Indianapolis, Decatur & Western Ry., where the system of making the foremen the judges was in use, the tabular results of the inspection, with appropriate praise or blame, were given in the annual reports of the company.

On the Pennsylvania Ry. the time for the inspection of the main line is selected by the general manager, governed somewhat by the time the board of directors makes its tour over the lines. It usually follows closely this inspection, which usually takes place about the middle or third week in October. This time of the month is fixed so as not to have the supervisors and others away from their divisions at the last of the month.

The inspection parties are of two classes: 1, The "Limited," in which those officiating comprise officials above the rank of supervisor; 2, the "Unlimited" or "General," in which officials down to and including assistant supervisors on all lines east of Pittsburg and Erie participate.

It is customary on the Monday of inspection week for the party comprising the "limited" inspection to leave Philadelphia, running special west, arriving at Pittsburg in the evening. This party is made up of the general manager, engineer of maintenance of way, general superintendents, superintendents of the divisions over which the inspection is made. principal assistant engineers and assistant engineers of the main line divisions between Jersey City and Pittsburg.

The "general" inspection party is made up of all the participants in the

inspection, who meet at Pittsburg prepared to move eastward on Tuesday morning. The movement of the inspection train is as follows: Tuesday over Pittsburg Division, Wednesday over Middle Division, Thursday over Philadelphia Division, Friday over New York Division. The inspection party is carried usually in separate trains, the first train carrying the general manager and his party; the second train carrying the principal assistant engineer and assistant engineers of all the divisions; the third train all the supervisors; fourth train all the assistant supervisors. These are followed by the indicator car in charge of the motive power department.

The various branch road inspections are arranged for by the division superintendents and usually follow the main line inspection. These are not held regularly, and not on all of the divisions.

In awarding prizes committees are appointed on each main line division and so arranged that no officer of the division that is being inspected is a member of any committee on award for that division. The prizes awarded after the annual main line track inspection are as follows:

First Supervisor's Prize, $100; for main line supervisor (exclusive of yard supervisors) having best line and surface between Jersey City and Pittsburg. (One prize.)

Second Supervisor's Prize, $50; for main line supervisor (exclusive of yard supervisors) having "second best" line and surface between Jersey City and Pittsburg. (One prize.)

Yard Supervisor's Prize, $100; for main line yard supervisor having best line and surface on yard between Jersey City and Pittsburg. (One prize.)

Foreman's Prize, $75; for main line foreman (exclusive of yard subdivisions) having best line and surface on any foreman's division between Jersey City and Pittsburg. (One prize.)

The premium section is not marked by any sign.

The use of the track indicator car is not considered as part of the inspection of the road, and has no connection with the annual inspection for prizes. The inspection car used on this road, and above referred to, resembles a large caboose, 36 ft. long over the end sills, and mounted on two four-wheel trucks with 33-in. wheels. The front end is open, and the floor slopes up by steps from this end to about the middle of the car, so that all the occupants may have a good view of the track. This part of the car is fitted with ordinary car seats, giving seating accommodation for 28 persons.

The Wabash Ry. has one of the best and most complete systems of track inspection, and gives enough prizes to make the men take particular interest in their work. The following are the rules of the Wabash Ry. for the annual inspection of track, this being made in November of each year, being conducted by the general superintendent, assisted by such officers as he may select:

Track Inspection Rules: Wabash Ry.

The annual inspection shall determine the condition of each section and division of main track and sidings, in the following particulars: 1, Line and surface; 2, level; 3, joints, ties and switches in main track; 4, drainage; 5, policing; 6, siding (meaning all tracks outside the main track, and these must be inspected, marked and kept separately from markings on main track). These conditions shall be determined by a system of marking, for every mile of road: 10 shall indicate perfection: 5 shall indicate

a condition unsafe for a speed of 25 miles per hour, and 0 the worst possible condition; intermediate numbers being used to indicate intermediate conditions.

The annual report shall show the total expense for labor for the year on each mile of main track, and each mile of side track, the rating being determined as hereinafter set forth. The yard sections shall be classified together for the first and second premiums, the same as the districts.

The final rating of each section, for classification, shall be made as follows: The conditions noted under the markings Nos. 1, 2, 3, 4 and 5, shall be reduced to an average rating, which, in a column of the report shall represent the general average for conditions noted on main track. The general average of conditions under marking No. 6, in its column, will indicate the general average of conditions noted on all sidings.

Sections having iron rail shall be allowed one point over steel rail; sections having steel rail in service eight years and upwards, half a point, provided this difference does not increase the result above 10. This point will be added to final average, and will not be noted by the inspectors. The sections on each division roadmaster's territory showing the highest general average shall be rewarded by a premium of $35 to the section foreman, and the second highest average by $25.

1. Line.—True line means straight line on tangents, and uniform curvature on curves, as far as the eye can detect. When these requirements are fulfilled the condition must be represented by 10.

Continuous and very apparent deviations from the true alinement over the entire length of one mile, which would limit the maximum speed for the safe passage of trains to 25 miles per hour, must be represented by 5.

A condition of alinement which would be difficult for a train to pass, should be recorded as 0.

Conditions intermediate between those described above shall be indicated in the proper ratio representing these conditions.

Surface.—True surface means a uniform grade line between changes of grade, and the conditions must be noted as in regard to Line.

2. Level.—The inspector must watch the level index, and must note unusual oscillations of the car due to unlevel track on tangents, want of uniformity of elevation on curves, or unequal gage.

If the inspector can detect no vibration or oscillation of the car due to unlevel track, on tangents, and want of uniformity on elevation of curves, he will record the condition as 10, and intermediate conditions must be recorded as already noted.

3. Joints, Ties and Switches.—A perfect joint is one that is fully bolted and tight. Ties must be properly spaced, as per standard plan, and fully spiked with four spikes in each tie. Ends of ties, one side must be parallel with rail. Switches must be placed exactly as shown in standard specifications. When these are fulfilled the condition must be represented by 10, and intermediate conditions recorded as already noted.

4. Drainage.—The ditches shall be uniform, free from obstruction, and with sufficient incline to afford proper drainage. Ballast shall be uniform and equally distributed. Any condition less than described in the foregoing will be represented by such fraction of 10 as it bears to the required condition.

5. Policing.—This shall consist of the following items, and a perfect condition in all these respects shall be represented by a marking of 10:

A. Cross-ties and iron must be piled according to the general rules.

B. Grass, bushes and weeds should be kept cut close to the ground within limits of right of way, and not allowed to grow closer than within 6 ft. of the rails. Stumps and logs should be cleared from within limits of right of way.

C. Road crossings must be in accordance with standard plans, and must be clear and safe for the passage of animals and vehicles.

D. Signs must be placed in position as required in standard clearance diagram.

E. Cross and line fences shall be kept in repair after being constructed

by fence gang. They shall be of standard plans. Cross fences and cattle guards shall be clear of all grass and weeds, and shall be whitewashed.

Any conditions less than prescribed in foregoing subdivisions will be represented by such fraction of 10 as it bears to the required condition.

Expense.—The section which is maintained at the least expense shall receive 10 points. The amount of expense on each section to be determined as follows: From the aggregate expense of the year shall be deducted the cost for extra work, such as placing ties, rails, ballast, and ditching, for which credit will be made as follows: Ties in rock ballast credited at 20 cts. per tie; ties in gravel, cinder or earth ballast, 8 cts. per tie; rock ballast credited at $2.50 per car, other ballast at $1 per car; rail laid credited at $1.50 per 100 ft.; ditching, at $1 per 100 ft. After this deduction is made the section showing the least expense will be marked 100, which, divided by 10, will give the rating of that section. For each additional $10 of expense over the lowest section for all other sections, deduct one point from 100 points, the remainder, after being divided by 10, shall be the rating of that section regarding expenses on the general report, and shall be recorded as the average expense of all miles on that section.

The inspection committee shall consist of six or more persons, or shall be arranged as shown on the accompanying form. (The form or card is 9½ ins. long, and 6 ins. high, with ten lines under the heading.) The general superintendent will assign duties to inspectors on the day of the inspection. The placing of different members of general committee on the several sub-committees will be performed by the officer in charge of inspection. Each member of these committees will be furnished with a form showing the conditions which he must note, upon which he must indicate the rating of each mile.

District	Section	Miles		Committee No. 1 2 Persons			Committee No. 2 2 Persons		Committee No. 3 2 Persons			Expense	Remarks
		Main Track	Side Track	Line	Surface	Sidings	Joints and Ties	Switches in Main Track	Drainage	Policing General	Policing Fences	Rating	
				1	2	3	4		5	6	6	7	

.... *Foreman* .... *Inspector*

Form of Inspection Marking Card; Wabash Ry.

The officer in charge of inspection shall take up all forms when rating has been placed thereon, and make a general report to the general superintendent, showing the rating of all sections as hereinbefore described, showing the names of all persons entitled to a premium. The general superintendent will then cause the awards to be made, and have signs placed on sections to which premiums have been awarded, which will indicate the standing of that section on each subdivision.

The form of the report is as shown on p. 340, being printed on sheets about

District.	Section.	Location.	Name of foreman.	Total expense for labor.	Length, miles.	Expense per mile for labor.	Rating of sections. Line.	Surface.	Sidings.	Joints, ties and switches; main track.	Drainage.	General.	Expense.	Average rating.	Premium section.	Remarks.	Roadmaster.
6th and 7th.	209	Ritchie	N. Anderson	$981.16	6.0	$163.52	9.3	9.3	6.9	8.8	8.8	8.6	9.5	8.742	...	....	John McKeown.
	210	**ESSEX**	**J. DONAHUE**	894.99	6.0	149.16	8.9	8.8	8.5	9.2	9.2	9.0	9.6	9.028	210	First prize..	" "
	211	Reddicks	Thos. Ferriter	901.91	6.0	150.31	9.1	9.1	7.0	9.3	9.1	9.2	9.6	8.914	...	....	" "
	212	*Campus*	*J. F. Ricketts*	975.56	6.0	162.59	9.2	9.1	7.0	9.3	9.4	9.2	9.5	8.957	212	Second prize	" "
	213	Essington	Michael Gust	1,083.25	6.0	180.54	9.2	9.1	7.0	9.3	9.3	9.0	9.3	8.885	...	....	" "

Form of Record of Track Inspection; Wabash Ry.

12 ins. wide and 24 ins. high. The line of the first prize is printed in heavy-faced type, and that of the second prize in italics.

On the New York, Pennsylvania & Ohio Ry. there is an annual inspection of track, and the Engineers of Maintenance of Way and Supervisors are taken over the entire system. The party consists of about 25 and is divided into five committees as follows: 1, Line and surface; 2, Joints, spikes and ties; 3, Ballast, switches and sidings; 4, Ditches, road crossings and cattle guards; 5, Policing right of way, and neatness of station grounds. Each individual member of the committee, as he goes over, marks each section or each station grounds, according to his idea of how they appear; 10, the highest number, means perfection, 5 being medium. The marking is done with reference to the actual condition as compared with his idea of perfection independent of all other consideration. These markings are then averaged by committees and by sub-divisions of each hundred miles, and the section having the highest marks of all is considered the premium section, and a sign to that effect is placed upon the tool house. Formerly there was given a premium of $50 to the section foreman having charge of the premium section, but this has been discontinued. The result probably is not very satisfactory as compared one year with another, but as compared with the condition at the time it is probably as good as can be obtained. The results of these markings are distributed to each supervisor and section foreman.

On the Columbus, Hocking Valley & Toledo Ry., a circular is issued by the chief engineer and the engineer of maintenance of way, to the supervisors, foremen and section men, giving a statement of the results of the inspection and announcing the

awards. The statement in the circular issued Dec. 5, 1896, is as follows:

"In announcing the results of the sixth annual track inspection, attention is called to the fact that the premiums are awarded for the greatest improvement resulting from the labors of trackmen during the year, proper allowance being made for the character of the rail and other materials with which they have to work. The company alone is responsible for the quantity and quality of the materials furnished, and those who have made the best use of such materials are entitled to the most credit. It is gratifying to note that the general condition of the track has improved during the past year from an average of 78.2% to an average of 80.4%, a gain of 2.2%. There has been a marked improvement in the condition of switches and frogs, and the leads connecting them. There is, however, a tendency to neglect to some extent the condition of sidings; with the constantly increasing loads and heavy traffic, it is important that careful attention should be given to all sidings, and special care taken of such as are used for passing trains."

The marking card used on the Southern Pacific Ry. has a vertical column for each section, and at the side of the card are printed the points to be marked with the highest rating (meaning perfection) in each case, as

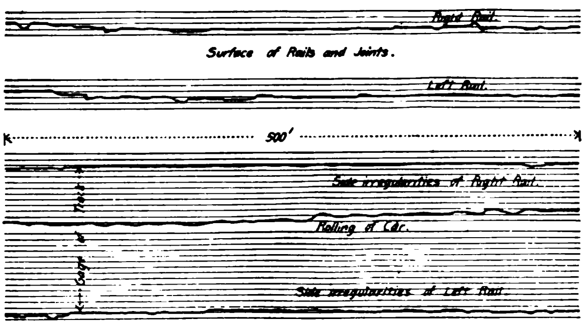


Fig. 208.—Track Diagram of Dynagraph Car; 80-lb. Rails.

follows: Alinement, 12; surface, 12; drainage, 12; switches and frogs, 10; houses and grounds, 10; spiking, 7; ties, line and spacing, 7; ballast, 7; sidings, 5; material, 5; grass and weeds, 5; road crossings and run-offs, 3; fencing, 3; right of way, 2; summary, 100. No fractions or decimals are used in marking. The tabular statement of the inspection shows the marking for each of these items on each section, with names of foremen, roadmaster, etc. The inspection party consists of all the officers who have jurisdiction over and connection with the maintenance of way department. No special committees are appointed to mark upon certain features of the track; and every person scoring is supposed to give on the cardboard form his views in regard to the condition of all the items contained on the score-card, as above noted. The prizes awarded are a gold medal and three silver medals; the gold medal for the roadmaster having the best division, and the silver medals for the foreman having the best section, the foreman having the best section-house, and the pumper having the best pump-house at the time of the inspection.

The system instituted some years ago by the Savannah, Florida & Western Ry. was as follows: Inspections were made annually by the higher officers and the engineers, and quarterly by the officers of the roadway department. Every mile was marked separately for the following items: 1, line; 2, surface; 3, level; 4, frogs and switches; 5, drainage; 6, policing. The maximum in each case was 10, and a committee of two was appointed

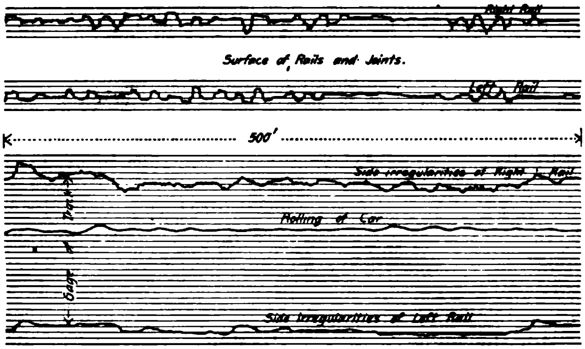


Fig. 209.—Track Diagram of Dynagraph Car; 80-lb. Rails.

to inspect and mark for each one of these items, this being considered to give a fairer comparison than when every detail is marked by every inspecting officer, and when every division or section is judged as a whole. The marking for each mile is an especially good feature, as no man, however energetic and conscientious, can watch mile after mile of track under various conditions, and then give any very reliable opinion as to the condition of several items. By the results of the annual inspection there were awarded five premiums; $100 to the supervisor of the best division; $50 to those of the two next best divisions; and $40 and $20 to the best and second best sections on each division. The section foremen are also classified as first, second or third class, according as the markings for their sections are over 8, over 6, or under 6. At the quarterly inspection prizes are awarded on each division as follows: $15 to the foreman showing the most improvement: $10 to the foreman having the smallest labor account without deterioration in the condition of his section (but if the section has previously had a low mark some improvement in condition is required to obtain this award); $10 to the foreman making the best progress in bringing the roadbed and track up to the standard condition, and $10 for the foreman having the least expense for tools per man.

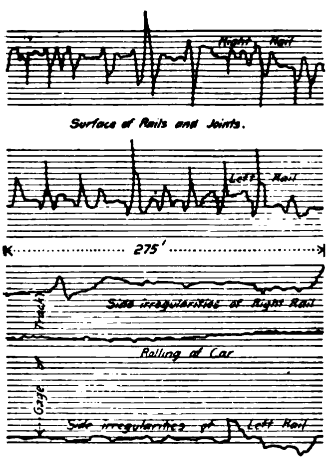


Fig. 210.—Track Diagram of Dynagraph Car; 65-lb. Rails.

Where the railway company does not offer premiums, this is sometimes done by the roadmaster in order to encourage his men to get and maintain good track. In one case of this kind a premium of $250 was awarded to the best section, of which $150 went to the foreman and the balance was divided among the laborers in proportion to the number of days worked by each man during the year. The condition of track and tools, amount expended, number of passes issued, and all matters pertaining to the work were taken into consideration.

All awards of this kind should be made on the principle that the greatest benefits should go to the men who secure the best results per dollar of expenditure, and not merely to those who have the best track, without taking the expense into consideration.

There is also in force a system of "mechanical inspection" by the use of dynagraph cars. These cars have track connections which follow every irregularity in line, surface and gage, record these in diagrams on a roll of paper, and mark bad spots with a jet of paint. The advantages of such inspection for ascertaining the general condition of track, and its comparative condition (by comparing diagrams taken at different times) can hardly

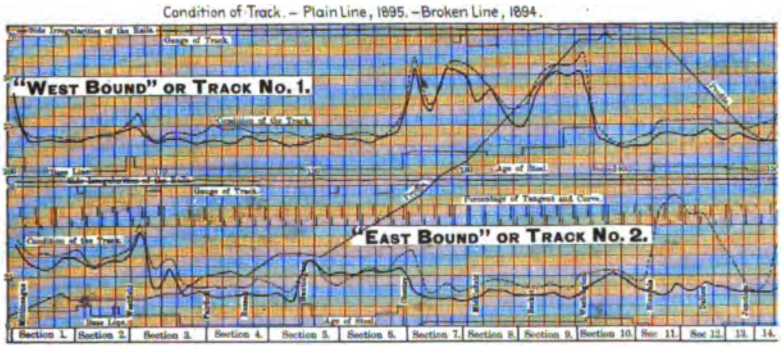


Fig. 211.—Condensed Track Diagram; Boston & Albany Ry.

be overestimated. By a study of the diagrams the work required on the sections can be seen at once, while the section foremen have their attention called to low joints, low spots, etc., the machine marking even to ⅛ or ¼-in. below the proper surface. The foreman will not be governed entirely by this in surfacing, but he will know that every paint mark means a low place, and that even if the rail is up to surface, the ties may be loose and work up and down in the ballast, or the spikes may be loose and allow the rail to stand free of the tie, which defects he could not detect by sighting for surface. The most complete and important machine of this kind is the dynagraph car designed by Mr. P. H. Dudley, who makes occasional or periodical inspections of numerous roads in this way, and then submits the report of his inspection.

Three examples of these diagrams (to a reduced scale) are shown in Figs. 208, 209, 210. Fig. 208 is from track laid with 80-lb. rails, 5⅛ ins. high, having three-tie joints; this track is in excellent condition. Fig. 209 is

from track laid with older 80-lb. rails, 5 ins. high, having three-tie joints; these rails were not straightened properly and had a wavy surface. Fig. 210 is from track laid with 65-lb. rails, 4½ ins. high, having suspended joints. The surface irregularities of the joints are very marked. Fig. 211 is a portion of the complete maintenance of way diagram plotted from these detailed diagrams.

The following particulars in regard to the diagram for the Boston & Albany Ry., Fig. 211, are taken from a statement accompanying the diagrams:

The spaces between the vertical lines on the diagram represent miles of road. The line marked "Condition of Track" for each inspection represents the average sum of all the various undulations of the rails per mile, as mechanically summed up by the inspection apparatus, into feet and inches per mile. To plot the sum of the undulations on the diagrams, the number of feet and inches per mile are reduced to inches and divided by 176 (the number of 30-ft. rails per mile), which gives the average undulations per rail per mile in hundredths of an inch. Each horizontal line on the diagrams represents one-hundredth of an inch, therefore as many above the base are taken as the average hundredths of an inch of undulation per mile. The results for each track are relative to the base line, yet are comparative one mile with another.

The average condition of each mile is indicated from the horizontal line crossed or touched by the condition of track line in the center of the space for the mile.

The line marked "Age of Steel" for each mile gives the length of service of the rails, each horizontal line representing one year.

The line marked "Percentage of Tangent and Curve" shows the approximate alinement of both tracks per mile. The percentage of tangent is marked on the left side of the space for the mile, and that of the curvature on the right side. Each horizontal line represents 10% for the mile.

The line marked "Profile" shows the grades of the road, and is common to both tracks, though ascending grades on one track are descending upon the other, and vice versa. Each horizontal line represents 10 ft. of elevation, and refers to the Base Line for track No. 2 in all cases.

The line marked "Gage of Track" reads downward from the Base, or 70th line, and shows the amount the track is wide gage, each horizontal line representing 1-10-in.; nearly every mile now shows perfect gage.

The line marked "Side Irregularities of the Rails," above the 70th line, represents the side irregularities of the rails, each horizontal line representing 1-10-in. This line reads from the highest point in the center of the space for the mile.

Three lines are about the best results which can be obtained.

At the end of 1895 three-fourths of the line was laid with 95-lb. rails, and the track, as well as the diagrams, showed a standard as remarkable as it was gratifying. The full calculated value for heavy and smooth rails shown in 1883, had not only been obtained, but the results were uniform for each division, irrespective of the grades and curves. Such a "Condition of Track" had not been generally believed possible of attainment either here or abroad, and it is evident that similar results could not be produced on either light or heavy round-headed rails.

Slipping of the locomotives on the ascending grades had been much reduced.

In ten years the undulations of the track had been reduced to one-third of their former amount even under an increase of double the freight-car wheel loads.

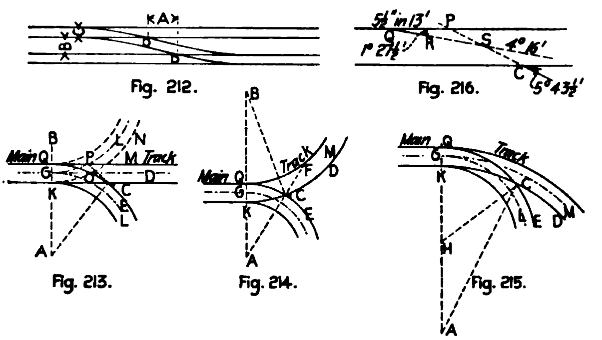
It requires smooth stiff rails, as well as skilled labor, to make a good track. Each year, as the skill of the trackmen increased, it became evident that the condition of the track depended as much upon the "Condition of the Steel" as upon the trackman; and to further improve the tracks it was not only necessary to introduce heavier and stiffer rails, but to have them finished smoother at the mills, and, in fact, to manufacture them under conditions which did not prevail before the 95-lb. rails were undertaken in 1890 and 1891.

The beneficial results of the work, in raising the standard of surfacing the track and the manufacture of the rails, are clearly defined on the diagrams.

A few roads have track indicator cars of their own, but with less complete registering and recording apparatus than Mr. Dudley's dynagraph car. The Pennsylvania Ry. car is carried on four spoke wheels, having long plate springs over the boxes. Behind one pair of wheels is a pair of deeply flanged small wheels which are connected with the mechanism of the recording apparatus in the car. This car is used for testing the tracks and recording the condition of the alinement, gage, surface, joints, superelevation of curves, etc. The mechanism records the condition of the track in these respects upon a roll of paper, making a continuous diagram, which may be used in issuing instructions for track improvement and for comparison with diagrams taken at other times. A useful device for smaller roads is a simple apparatus which can be attached to a hand car or the superintendent's car, by which the line and surface of the rails are recorded as a diagram. Such a device is in use on the Chicago Great Western Ry.

CHAPTER 20.—SWITCH WORK.

Where one track is to diverge from another a turnout is used, consisting of a switch to direct the train onto one or other track as desired, a frog to allow wheels to pass the rail intersection, and lead rails to connect these parts. The simplest arrangement is that shown in Figs. 44 and 217. A crossover consists of two turnouts and a short piece of diagonal track,



Switch Work Diagrams.

connecting two parallel tracks, as in Fig 212. A thoroughfare track or ladder track crosses several parallel tracks, as in Fig. 53, and a lead track is a diagonal track from which diverge a number of parallel tracks, as in Figs. 144 and 218.

The laying out of switch work is often regarded by engineers and practical trackmen as a very complicated and difficult operation, involving intricate mathematical work. This idea is due largely to the number of formulas and calculations which have been devised, and to the great fond-

ness which many engineers have for certain pet formulas. Each man regards his own as the "only" formula, whereas in practical work there is little to choose between them, the difference being usually merely apparent in theoretical work. The late Mr. A. M. Wellington, who was a thoroughly practical and theoretical man, strongly pointed out that a good turnout curve may be laid out by almost any of the innumerable formulas and tables, for the very good and sufficient reason that within quite wide limits it makes no particular difference what is the length of the turnout lead. In this connection is given the following concise and simple statement written by Mr. Wellington some years ago and published in the "Railway Gazette."

The Whole Art and Mystery of Laying Out Turnout Curves.

Frogs are made of certain even numbers, and the number is the primary unit to which all else is adjusted.

The number of a frog is its $\frac{\text{length}}{\text{width at back}}$, and is also sometimes called its proportion. A "No. 10" frog is one with sides sloping toward each other 1 in 10.

The frog-angle is $\frac{\text{57 deg. or 3420 min.}}{\text{No. of frog.}}$

Usually main line frogs are No. 8 and No. 10; sometimes Nos. 9 and 11. Few frogs sharper than No. 6 are used in any location, but as sharp as No. 4 sometimes occur on quick turnouts from curves.

The theoretical lead = twice No. of frog × gage = 9.42 × No. of frog, for standard gage. This assumes the curve to be a simple circular arc, which is not essential for a good curve, nor does it give the best, and considers the curve to extend back to the heel of the switch rail of a stub switch.

The lead is always the same, whether the turnout be from a tangent or a curve.

A difference of not exceeding 10% in length of lead, especially if the lead be made longer than above, has no appreciable injurious effect on the character of the turnout curve or on its radius. This is best seen by calling the turnout curve a parabola, and remembering that whether the tangents of a parabola be equal, or one 20% longer than the other, will not affect the excellence of the curve, nor, materially, the sharpest radius. Whether the curve be called a circle or parabola will not alter its position on the ground by more than a hair's-breadth.

To lay out the turnout curve, the frog being in place, and length of lead given, not differing more than 10% from the theoretical lead.

Practically, the best transit for running in the curve, and the only one much used for fixing points on it, is an experienced eye. Nevertheless, on all kinds of turnout curves, whether from tangent or curved main track:

Offset from gage side of main rail to gage side of lead rail at middle point of lead = ¼ gage, or 14 ins.

Offset at ¼ point of lead = 1-16 gage, or 3½ ins.

Offset at ¾ point of lead = 9-16 gage, or 31¾ ins.

With stub switches: Main frog to crotch frog = 0.3 of the theoretical lead; length of switch rail = 0.3 of lead and as much longer as convenient; main frog to head-block = 0.7 of lead. Position of crotch-frog not essentially affected by 10% increase of lead, but somewhat farther from main frog (some 3%). The back end of switch-rail should be spiked fast for a portion of its length and it will spring into a circular arc.

Calling the switch-rail straight, and starting the lead from it as from a tangent, compounds the curve at the head block and makes the switch-rail a tangent to a new arc. Its practical effect is to lengthen the lead by 6

to 10%, which gives a better curve, not because the assumption on which it rests (that the switch-rail remains straight) is true to fact, for it is not, but because it eases the radius of the first half of the curve.

Shortening the lead 10% requires an equal distance near the frog to be tangent to it, and shortens the turnout radius and proper length of switch-rail 20%.

Split Switches.—The gage side of the split rail is straight; therefore it can only be considered, when in place, as a tangent to the true turnout curve. The point at which the theoretical turnout curve attains an offset of the width of a rail head (say 2¼ ins.) from the main line is 0.8 of the theoretical lead from the frog. Hence to obtain the same turnout curve with a split switch as with a stub switch, the lead should be ($0.8 \times 9.42 \times N$) or $7.54 \times N$ + the length of the planed portion of the head of the point rail. Split switch leads, in other words, other things being equal, should be a little shorter than stub switch leads. But as all turnout curves are improved by being a little longer than a simple circular arc requires, a lead fixed by the rule $9.4 \times N$ is good practice for split switches.

Radius.—By the principle of proportional triangles it will be seen that the radius = Lead × No. of frog = (No. of frog)² × gage. This only holds on turnouts from tangents.

Degree of turnout curve = (plainly)

$$\frac{\text{frog angle}}{\text{lead in stations of 100 ft.}}$$

$$\frac{57^\circ}{N} \div \frac{2\,N\,g}{100} = \frac{606}{N^2},$$

or, in round numbers: 600 ÷ square of the number of the frog. If the turnout befrom a curved main track, add to the degree thus obtained the degree of the main curve, if the turnout is to the inside of the curve; and subtract it, if to the outside.

In the three diagrams, Figs. 213, 214 and 215, K C is the frog distance, or tangent distance from headblock to frog point; D C E is the frog angle, and O is the crotch frog, which is 7-10 of the frog angle number D C E. Taking an ordinary turnout, as in these figures, it will be seen that the turnout rails should conform to a curve tangent to the main and turnout tracks. If the turnout leaves a straight main track, the frog angle D C E will equal the intersection angle C P M, and the central angle B A C. The turnout curve must be one fitting the tangents Q P and P C. When the main track is curved, and the turnout curves in the opposite direction, the frog angle D C E will be equal to the sum of the central angles A B C and B A C (= F C B). When the main and turnout curves are in the same direction, the frog angle D C E will be equal to the difference between the central angles C H G and C A G (= A C H). The latter arrangement should be avoided wherever practicable, as it sharpens the frog angle, which is always undesirable. With a split switch, the lead K C (called also point lead or fixed lead) is from the point of the turnout. With a stub switch, the lead (called also stub lead or fixed lead) is from the headblock, differing from the point lead by the length of the moving rail. As a matter of fact, however, the split switch rail cannot be so thrown as to conform to the theoretical curve if made 15 ft. long, with the splice joint as the hinge. In this case the switch rail is usually taken as a straight line, so that (as in Fig. 216) the intersection angle, R S P, will not be the same as the frog angle, but will be the frog angle minus the switch angle. In other words, the curve must fit the tangents R S and S C, instead of the tangents

Q P and P C. The simple formula: Lead = 2 g n (or twice the gage multiplied by the frog number) gives the distance from the heel of switch to the point of frog on a regular curve. For instance, with gage 4.7 ft. and a No. 10 frog, the lead will be 94 ft., which includes the switch rails. With a split switch the theoretical length of switch rail for a No. 10 frog is 28 ft., but practically 24 ft., on account of the sharp planing necessary to get the exact curve from heel of switch to point of frog. This shortens the length of the lead 4 ft., but does not shorten the curve practically, as that begins back of the point unless the planing is very fine. A 15-ft. switch-rail is too short for main track switches, and 21 or 24 ft. rails make better work.

It is a mistake to consider the frog as a straight line, thus shortening the lead and sharpening the curve. It should conform to the turnout curve, and it will be found that trackmen who understand their work will spike the frogs to a curve if the alinement requires it, thus getting the easiest riding track with least maintenance and least danger of derailment. If the frog is straight, however, a straight rail should be laid beyond the heel, to make an easy riding turnout. For frogs over No. 7, the theoretical or "long" lead gives a flattened curve between the frog and the switch (thus making the frog sharper), and if the switch rail is considered as not conforming to the theoretical curve, a "short" lead is used, equivalent to the theoretical lead minus the length of switch rail. This is calculated by multiplying the frog number by twice the gage between main and turnout rails at the heel of the switch. For instance, with a clearance of 3 ins. at the heel, the distance betwen gage lines of stock and switch rails is about 5½ ins., which subtracted from the standard gage gives 4 ft. 3 ins., or 4.25 ft. The "short" lead for a No. 10 frog would thus be 90 ft. As a matter of fact, however, a difference of 5 to 10% in the length of turnout curve is not of practical importance, and it is simpler and equally satisfactory to stick to the old rule

$$\text{Lead} = 2\,g\,n.$$

A more detailed lead formula is:

$$\text{Lead (K C, Fig. 213)} = \frac{2\,(g - a)\,n - 2\,f}{1 + n\,t}$$

Here g = gage; a = distance between gage lines of main (or stock) and switch rails at the heel; n = frog number; f = distance from point of switch to toe; t = angle made by switch rail with main rail (switch angle). A more practical calculation, applicable to all customary lengths of lead is: Lead = 6¼ n or 6 n. The lead is practically the same for turnouts from tangents and from curves, and it is of no effect to lengthen the lead from the curve unless a correspondingly higher frog number is used, and where the turnout is on the inside of a main track curve the frog number should be as high as possible. Suppose a turnout is to leave the inside of a 4° main track curve, with a switch angle of 1°20′ and a frog angle of 7°10′. The lead, as found from the tables or by calculation is 59 ft. A 4° curve turns 2°19′ in 58 ft., and this added to the frog angle gives a total angle of 9°29′ To meet this we have the switch angle of 1°20′ and the curvature of the turnout, and subtracting the switch angle leaves 8°9′ to be turned by the turnout curve in 58 ft., which will require a curve of about 14°.

To set out the curve of lead, stretch a cord from the theoretical point of frog (as measured from K, Fig. 213, and marked on rail), to the point of curve Q C or R C, allowing for proper spread of switch rail heel. Divide this distance into four parts, and (for standard gage) set off a middle ordinate of 1.177 ft. and two side ordinates of 0.883 ft. From each of these points, and from the frog point and point of turnout, measure half the gage, which will give five points on the center line of the turnout curve. Each side ordinate is ¾ of the middle ordinate. At the middle point of the lead the offset from main rail to turnout rail (gage to gage) is always ¼ the gage, and at the quarter points it is 1-16 and 2-16 the gage, whatever may be the frog number, length or lead, or whether the turnout is from a tangent or curve. The degree of the turnout curve is 600 divided by the square of the frog number (approximately) when the turnout is from a tangent, and this, plus or minus the degree of main curve gives the degree when the turnout is from the inside or outside of a main line curve. The middle ordinate for bending 30 ft. rails is 12 ÷ square of frog number more (or less) than the main curve ordinate, and for other rail lengths, it is in proportion to the square of the respective lengths. If the degree (D) of turnout curve is known, the middle ordinate of a 30-ft. rail is 0.02 D.

When putting in a turnout the exact point of commencement is rarely arbitrarily fixed, but may be so located that the heel or toe of the frog can be attached at a rail joint, thus preventing one cutting of the rail. The plan in Fig. 67 shows the arrangement adopted by the Southern Pacific Ry. to prevent cutting the rail. From the point selected measure along the rail the distance from toe (or heel) of frog to the theoretical frog point, and mark the rail with chalk. Then from this mark measure the distance to the headblock or heel of switch as given by the table. From the headblock the distance c. to c. of ties is marked on the rail flange to facilitate laying. The fact that close accuracy or fine work is not necessary in practical work is recognized on many roads, and the switch diagrams of the Atchison, Topeka & Santa Fe Ry. bear the note that the location of any frog may be varied a foot or two when such change will avoid the cutting of a rail. On this road, stakes for turnouts are always set by the engineering department, which is certainly the best practice.

The rails for the main rail opposite the frog should be put in first, and the switch ties then laid. The frog is then put in place, the switch rails laid and connected up, and the bent rails then laid. The track is then spiked, the turnout rail being spiked snugly to gage at its bend, but not spiked beyond the bend. Then line up the main track, spread the bent rail at the heel of the switch the calculated distance, and line this rail straight from the end to the bend already spiked. The practice of the Boston & Albany Ry. in setting up split switches is as follows: Place the unbroken or main track rail in position, carefully lining it, and spiking as much of it as will not interfere with the switch. Then place the switch in position, and tamp the switch ties and headblock so that they will not shift or settle. Set the point of the switch hard against the main track rail, as if set for the sidetrack, tacking the point and spiking the heel. Erect the gate for this position of the switch, attach the rod, spike the gate to the headblock, and spike the brace plates against the main track rail. Remove the spike from the point and throw the switch by operating the gate. Lay the turnout rail against the point of the switch while in this position

and test the gage at the heel. Then spike the brace plates against the turnout rail, and the switch is complete.

Trackmen are apt to set the point of the switch rail too near the bend in the turnout rail, but it should be at least 24 ins. from it. The bend in this rail should be made carefully, and should not be a curve, but should be an angle as nearly as possible conforming to the angle of the switch rail, or switch angle.

Table No. 32 has been compiled by the author from the standard diagrams of the New York, New Haven & Hartford Ry., and shows the practice on that road. The reference letters are given on Fig. 217. The switch rails are all 15 ft. long, except for turnouts with No. 15 frogs, where they are 24 ft. long, 14 ft. being straight and 10 ft. on the turnout curve. All the switches have a throw of 3⅞ ins. The rigid frogs have a spread of 5 ins. at the toe (G), and 10 ins. at the heel (H), while the spring rail frogs have a spread G of 9⅝ ins. With 100-lb. rails the spread at the heel of the switch is greater than with 74-lb. rails. All ties are

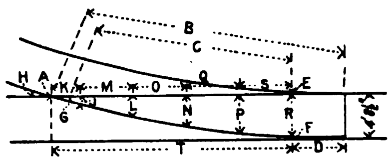


Fig. 217.—Diagram of Turnout.

7 × 9 ins. The guard rails are 15 ft. long, being straight for 9 ft. with a flangeway of 1¾ ins.; each end is flared to give a flangeway of 2½ ins. at 18 ins. from the end of the straight portion, and 4¾ ins. at the end of the rail. A guard-rail clamp is placed at each end of the straight portion.

The Columbus, Hocking Valley & Toledo Ry. gives the following rules:

1. To find the distance (K) from origin of curve to point of frog.—Multiply twice the gage by the frog number.

2. To find the radius of turnout curve.—Square the distance K and divide it by twice the gage.

3. To find length of switch rail.—Square the radius; then square the radius minus the throw of switch; subtract the latter from the former and extract the square root.

4. To find the distance between the frog points of a crossover, (measured parallel to the tracks) when the tracks are straight and parallel.—Subtract twice the gage from the distance center to center of tracks, and multiply the remainder by the frog number. Thus for No. 8 frogs and a distance of 13 ft. c. to c. of tracks it will be

(9 ft. 5 ins. — 13 ft.) × 8 = 28 ft. 8 ins.

The method of putting in turnouts by offsets from the main rail to the lead rail is sometimes followed, and this is shown by Table No. 33, the letters in which refer to Fig. 217. The distances given are measured from the gage side of the rail head.

These figures may be used on curved as well as straight track, provided the curve is a regular one. If the frog is on the inside of the curve, add the degree of the main curve to the degree of the turnout curve to obtain the curve of the lead. If the frog is on the outside of the curve, subtract

TABLE NO. 32.—TURNOUTS; NEW YORK, NEW HAVEN & HARTFORD RY.

Weight of rail, lbs. per yd.	74	74	74	100	74	74
Frog number	6	7	8	8	9	10
Style of frog	Rigid.	Rigid.	Rigid.	Rigid.	Rigid.	Rigid.
Angle of frog (A)	9° 33′ 38″	8° 11′ 30″	7° 10′	7° 10′	6° 22′ 10″	5° 43′ 54″
Lead (calculated), point of switch to point of frog, (B)	56 ft. 9 ins.	62 ft. 7¼ ins.	68 ft. 2 ins.	66 ft. 3 ins.	72 ft. 9¼ ins.	78 ft. 7¾ ins.
Lead (calculated), heel of switch to toe of frog (C)	39 " 3 "	44 " 8¼ "	49 " 10 "	47 " 11 "	54 " 0¼ "	59 " 5¾ "
Lead (actual), point of switch to point of frog, (B)	56 " 9 "	63 " 2½ "	68 " 8 "	66 " 8 "	73 " 1½ "	79 " 7 "
Lead (actual), heel of switch to toe of frog, (C)	39 " 0 "	45 " 0 "	50 " 0 "	48 " 0 "	54 " 0 "	60 " 0 "
Rails for lead C (No. and length)	(1) 24, (1) 15	(1) 30, (1) 15	(1) 30, (1) 20 or (1) 26, (1) 24	(2) 24	(1) 30, (1) 24 or (1) 28, (1) 26	(2) 30
Radius of lead curve (C), ft.	284.29	391.99	517.55	517.98	656.33	834.81
Length of switch rail, ft. (D)	15	15	15	15	15	15
Throw of switch rail, ins.	3⅞	3⅞	3⅞	3⅞	3⅞	3⅞
Angle between switch rail and main rail (E)	1° 39′	1° 39′	1° 39′	1° 52′	1° 39′	1° 39′
Spread at heel of switch rail, ins. (F)	5 9-16	5 9-16	5 9-16	6¼	5 9-16	5 9-16

Weight of rail, lbs. per yd.	74	100	100	74	74	100
Frog number	10	10	10	12	15	15
Style of frog	Spring.	Rigid.	Spring.	Rigid.	Rigid.	Rigid.
Angle of frog (A)	5° 43′ 54″	5° 43′ 54″	5° 43′ 54″	4° 46′ 34″	3° 49′ 12″	3° 49′ 12″
Lead (calculated), point of switch to point of frog (B)	76 ft. 6¼ ins.	76 ft. 1 ins.	74 ft. 1½ ins.	88 ft. 4 ins.	114 ft. 11¼ ins.	111 ft. 7¾ ins.
Lead (calculated), heel of switch to toe of frog (C)	53 " 6 "	56 " 11 "	51 " 1¼ "	68 " 4 "	84 " 8¼ "	81 " 4¾ "
Lead (actual), point of switch to point of frog, (B)	77 " 2¼ "	75 " 7 "	75 " 7¼ "	88 " 6 "	114 " 10⅛ "	112 " 10½ "
Lead (actual), heel of switch to toe of frog, (C)	54 " 0 "	56 " 0 "	52 " 0 "	68 " 0 "	84 " 0 "	82 " 0 "
Rails for lead C (No. and length)	(1) 30, (1) 24 or (1) 28, (1) 26	(2) 28 or (1) 30, (1) 26	(2) 26 or (1) 28, (1) 24	(1) 30, (1) 28 and (1) 10,	(2) 30, (1) 24	(1) 30, (1) 28 and (1) 24
Radius of lead curve (C), ft.	750.85	843.36	757.26	1,252.71	1,947.42	1,973.93
Length of switch rail, ft. (D)	15	15	15	15	24	24
Throw of switch rail, ins.	3⅞	3⅞	3⅞	3⅞	3⅞	3⅞
Angle between switch rail and main rail (E)	1° 39′	1° 52′	1° 52′	1° 39′	1° 2′	1° 10′
Spread at heel of switch rail, ins. (F)	5 9-16	6¼	6¼	5 9-16	3 7-16 at 14 ft., 5⅞ at 24 ft.	3 13-16 at 14 ft., 6 9-16 at 24 ft.

the degree of the main curve from the degree of the turnout curve to obtain the curve of the lead, or vice versa.

If the turnout is from the inside of a very sharp curve, it is better to use a frog of as small angle as possible, to reduce the curvature in the lead to a minimum. If the turnout is from the outside of a very sharp curve, it is well to put in a frog of such number that the lead will either be straight or curve slightly in the opposite direction from the main curve.

TABLE NO. 33.—LAYING OUT TURNOUTS BY OFFSETS.

Frog	Rigid.	Spring.	Spring.	Spring.
Frog, number	6	8	10	12
Frog angle ....A	9° 32′	7° 10′	5° 44′	4° 47′
Clearance at heel of switch.....F	5½ ins.	5½ ins.	5½ ins.	5½ ins.
Length of switch rail..........D	15 ft.	15 ft.	15 ft.	15 ft.
Point of switch to point of frog..B	56ft. 4¾ ins.	65 ft. 6⅝ ins.	76 ft. 8⅛ ins.	86 ft. 9 ins.
Heel of switch to frog point (measured along the rail)......T	41 " 4¾ "	50 " 6⅝ "	61 " 8⅛ "	71 " 9 "
Lead curve	20° 26′	12° 38′	7° 20′	4° 43′
Offset from main rail to lead....J	5½ ins.	10¾ ins.	8½ ins.	7 ins.
" " " " " " L	1 ft. 7¾ ins.	2 ft. 4⅛ ins.	1 ft. 7 ins.	1 ft. 10 ins.
" " " " " " ....N	3 " 4¾ "	3 " 6½ "	2 " 9⅛ "	2 " 10¼"
" " " " " " ....P	....	....	3 " 1⅞ "	8 ft. 8 ins.
" " " " " " ....R	4 ft. 3 ins.	4 ft. 3 ins.	4 " 3 "	4 " 3 "
Distance, frog point to offset....K	8 " 0 "	7 " 6 "	7 " 6 "	7 " 6 "
" " " " " ...KM	11 " 4¾ "	20 " 6 "	16 " 8⅛ "	23 " 9 "
" " " " " .KMO	26 " 4¾ "	35 " 6 "	31 " 8⅛ "	39 " 9 "
" " " " " KMOQ	....	....	46 " 8⅛ "	55 " 9 "
" " " " "KMOQS	41 ft. 4¾ ins.	50 ft. 6 ins.	61 " 8⅛ "	71 " 9 "

The main track should be set to true line before the frog is put in. The measurements are calculated from the theoretical point of frog, but are changed so as to be read correctly from the actual point.

It is usual to issue switch diagrams, showing the leads, etc. On the Michigan Central Ry. no attempt is made to get the middle ordinate for a lead which is not a simple curve, but the tables showing graphically the standards for putting in switches are based upon the assumption that the proper lead consists of a simple curve uniting the switch rail (or the switch points) with the tangent of the frog leg, and ordinates are given for spiking such leads. Of course the presence of streets and obstructions makes it occasionally necessary or desirable to vary these leads to a greater or less extent. Unless such emergency exists, however, the standard is used, and the foreman's eye has to take care of the particular departure from this standard which he may have to make.

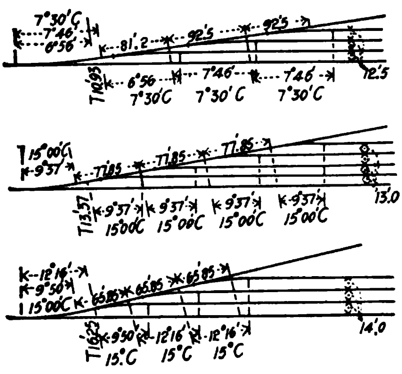


Fig. 218.—Layout of Yard Entrances; A., T. & S. F. Ry.

In three-throw switches, Fig. 52, the distance from the crotch frog to the main frog is 0.3 × theoretical lead; or approximately 3 × frog number. In putting in the crotch frog of a three-throw switch, when both of the side frogs are of the same number, put in one lead first and line it up properly. Then take the track gage and move it along the track until the center point is over the center of the lead rail, which will be the place for the point of

the crotch frog. For crossovers between parallel tracks, the distance between the frog points (measured parallel with the rail) is the distance c. to c. of tracks, minus the gage, and multiplied by the frog number. In laying out large yards it is best to lay out the arrangement of tracks on paper on a large scale, and then take off the angles, leads, etc., by measurement. Examples of the layout of the yard entrances (taken from diagrams issued by the Atchison, Topeka & Santa Fe Ry.) are shown in Fig. 218.

Crossovers.—A crossover is a diagonal track connecting two parallel tracks, and consists of two turnouts which are usually connected by a short tangent, although where space is limited and the crossover is to be used only at slow speeds it may have the turnout curves united as reversed curves, intersecting at a line connecting the centers of the curves. Wherever possible, the crossover should be laid out with trailing switches, so as to offer no danger to direct main track movements, being used only by backward movements. The length of the crossover will depend upon the frog number and the distance between tracks (measured between the gage sides of the rail heads). The rule of the Columbus, Hocking Valley & Toledo Ry. for ascertaining this has been given above. In Fig. 212, A = distance between frog points (measured along the main track), B = distance between gage sides of inner rails of the two adjacent tracks, C = gage of track, D = frog number. Then

$$A = (B - C) \times D.$$

For a turnout with frogs of different numbers, D and D'; first find the distance A for D and for D' by the above formula. Then half the sum of these two distances will give the distance A for the required combination. The diagonal distance D D between frog points is obtained by the following formula:

$$\sqrt[2]{B^2 + A^2}$$

Instructions for Switch Work.—As already noted, it is the general practice to issue tables and instructions as to details of switch work, and below are given the instructions issued by the engineering department of the Chicago & Northwestern Ry. governing the putting in and the maintenance of split switches, spring rail frogs and movable point frogs:

Rules for Maintenance of Switches and Frogs; C. & N. W. Ry.

In putting in spring rail frogs there should be a full allowance of 3-16-in. clearance left at each end of the frog to the adjoining rails. For a distance of four rail lengths back from the heel of the frog the angle bars should be fully spiked in the slots to prevent, as far as possible, the crowding forward of the main track rails. The anchor block at the spring rail end of the frog should be in every case put in and fully bolted. After the frog is in and oiled up, the spring rail should be tested to see that it moves back to its proper place, and that the side lugs are clear of the caps on the slide plates. In the subsequent care of the frog these lugs should be kept clear of the caps, and the frog kept clean and oiled the same as split switches are.

The spring rail frogs, movable point frogs and split switches should be regularly inspected by the roadmaster to see that all bolts are kept up tight and cotters in place where provision is made for them. Particular attention should be paid to the surface of the ties so that the movable rails have an even and uniform bearing on all of the side plates. A very common, and also dangerous, condition is that in which the ties at or near the joint fastening become lower than those adjoining them, so that the bent portion of the spring rail of spring rail frogs, and points of movable point

frogs and split switches will rise as the wheels pass off from the movable rail at this joint. The middle of the moving rail resting on the high ties, and the point end being depressed to a hollow bearing on the low ties under them, causes the free end to play up and down.

For spring rail frogs on the main track side, a 15-ft. guard rail should be used which should be placed 1¾ ins. from the gage of the main track rail, the gage of the main track being 4 ft. 8½ ins. This guard rail should be placed so that wheels moving toward the point of the frog will be guided from a point 8 ft. in advance of the point of the frog. This will put two-thirds of the guard rail in advance of the point of the frog, and one-third back of it. The guard rail should have not less than four rail braces fully spiked down to support it.

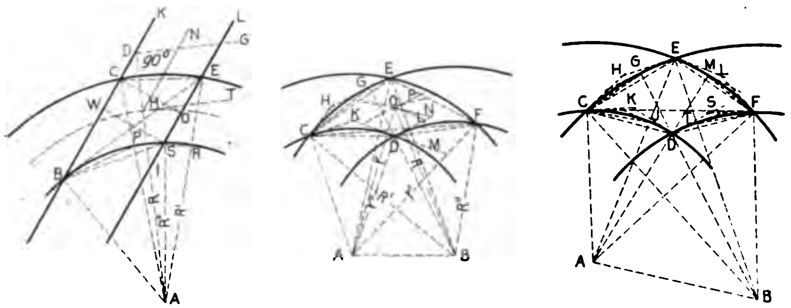
On all split switches there should be a wooden block bedded between the ties under the switch connection rod, clearing the latter by not more than ½-in., and placed 1 ft. from the switch stand, so that if the nut should come off from the lower end of the switch stand stem, the connecting rod cannot drop off from the crank and leave the point loose and free. Where practicable, a better device than this would be to have a bent wrought strap which would be spiked down on the ties and passed under the connecting rod.

Great care should be exercised to see that the gage is maintained true at split switches and at movable point frogs, and that points are kept free from snow and ice and fit snugly against the main rails in either the position for the main track or for the siding.

Moving Switches by an Engine.—Occasionally it will be found necessary to move a system of switches, or a leader in a yard, to accommodate some other improvements. If the distance is not too long for a wrecking rope, or combination of short ropes, an engine can pull one turnout at a time readily, and this plan has been followed on the Lehigh Valley Ry. First remove the track intervening between the old and new locations, excavate the ballast to the bottom of the ties, cut the track loose between the turnouts, and put 1-in. boards under the ends of the switch timbers, lapping them in the direction the switch is going to be pulled. Fasten each end of a chain around the rails and sill on each side of the switch, preferably behind a joint, and hook the engine rope to the middle of this chain, so as to prevent the strain from being greater on one side than the other, and thus twisting the switch timbers. The engine will then pull the turnout to its required position. Put in the connecting rails and splice up the track. The engine now moves ahead, prepared to pull each consecutive turnout in like manner. A leader has been moved in this manner in one day, which could not possibly have been done by hand with the same force of men in ten days.

Crossings.—The calculations for crossing frogs at track intersections are apt to be somewhat complicated. The crossings should always be put in under the direction of an engineer, stakes being set to mark the center lines of the two tracks, and nothing being left to the trackmen to do in the matter of making measurements. Whenever it is necessary to do any lining at crossings, it should always be done with reference to stakes set by the engineers. The practice on the Michigan Central Ry. is to take the angle of a crossing frog in the track with a transit, and then confirm the observed angle by tape measurements. The point is found at which the gage lines of the frog meet, and then a mark is made on the gage side of each rail forming the frog at a distance of 3 ft. from the intersection of the gage lines, measured toward the heel of the frog. The distances between these marks is measured and divided by 6, which gives the line of

half the angle of the frog. This angle is of course the angle of the crossing if both tracks are straight lines or tangents. If the crossing is formed by one straight and one curved track, or by two curved tracks, the intersection of gage lines at each of the four corners of the diamond is found, also the angle of each frog in the manner stated above. All the connecting distances between the intersections of gage lines are also measured. These



Case 1. Case 2. Case 3.

Fig. 219.—Track Crossings at Grade on Curves.

measurements are simply to confirm calculations, which calculations are anything but simple. As this is a detail of track work not generally treated of outside of railway offices, the following three diagrams (Fig. 219) and sets of calculations are given, which represent the practice on the Michigan Central Ry:

Case 1.—Crossing of Curved Track and Straight Track.—Calculation of the Frog Angles and Chord Lengths:

Observe the central angle $\overline{NHT}$.

D, R = radius central curve.

" R' = R + ½ gage.

" R'' = R − ½ "

Let F, F', F'', F''' = Frog angles at S, B, C, and E.

$\overline{NHT} = \overline{KDG}$. $DH = HI = \dfrac{\frac{1}{2}\text{ gage}}{\cos \overline{KDG}}$. $AD = R + DH$. $AI = R - HI$.

$\overline{CDA} = 90^\circ - \overline{KDG}$. $\overline{EIA} = 180^\circ - \overline{CDA}$.

$\sin \overline{KBA} : AD = \sin \overline{CDA} : R'$ $\therefore \sin \overline{KCA} = \dfrac{AD \times \sin \overline{CDA}}{R'}$.

$\sin \overline{KBA} : AD = \sin \overline{CDA} : R''$ $\therefore \sin KBA = \dfrac{AD \times \sin \overline{CDA}}{R''}$

$\sin \overline{IEA} : AI = \sin \overline{EIA} = R'$ $\therefore \sin \overline{IEA} = \dfrac{AI \times \sin \overline{EIA}}{R'}$

$\sin \overline{ISA} : AI = \sin \overline{EIA} = R''$ $\therefore \sin \overline{ISA} = \dfrac{AI \times \sin \overline{EIA}}{R''}$

$90 - \overline{ISA} = F$. $90 - \overline{IEA} = F'''$ $\overline{KBA} - 90^\circ = F'$ $\overline{KCA} - 90 = F''$

To find chord lengths. $\overline{WBS} = F' + \frac{1}{2}(F - F')$. $\overline{OEC} = F''' - \frac{1}{2}(F''' - F'')$

$\overline{CBP} = F' + \frac{1}{2}(F'' - F')$. $\overline{BPC} = 90^\circ + \frac{1}{2}(F'' - F')$

$\overline{ESR} = F + \frac{1}{2}(F''' - F)$. $\overline{SRE} = 90^\circ + \frac{1}{2}(F''' - F)$

$BS = \dfrac{\text{gage}}{\sin WBS}$. $CE = \dfrac{\text{gage}}{\sin OEC}$.

$\sin \overline{CBP} : \text{gage} = \sin \overline{BPC} : BC \quad \therefore BC = \dfrac{\sin BPC \cdot g}{\sin CBP}$.

$\sin \overline{ESR} :\ \text{"}\ = \sin \overline{SRE} : SE \quad \therefore SE = \dfrac{\sin SRE \times g}{\sin ESR}$

To check, compute side BE from the triangles BSE and CBE.

Case 2.—Crossing of Two Curved Tracks.—Calculation for the Frog Angles and Chord Lengths:

Observe the central angle $\overline{NOP}$, or any frog angle, as $\overline{HCK}$.

AB = Distance between the centers of the two curves.
R = Longer radius of center line.
r = Shorter radius of center line.
$R' = R + \frac{1}{2}g$, $R'' = R - \frac{1}{2}g$, $r' = r + \frac{1}{2}g$, $r'' = r - \frac{1}{2}g$.

1. If central angle is known, $\overline{AOB} = \overline{NOP}$. In triangle AOB, $\tan \overline{ABO} = \dfrac{r \cdot \sin AOB}{R - r \cos \overline{AOB}}$, and side $AB = \dfrac{r \cdot \sin \overline{AOB}}{\sin \overline{ABO}}$.

2. If a frog angle is observed, as $\overline{HCK}$, find AB in like manner from triangle ABC.

3. All the sides of the triangles ACB, AEB, AFB and ADB, being known, compute all the angles of each triangle. The angles at C, E, D and F, thus found, will be the Frog Angles required.

4. To find the chord-length CD, produce BD to G; $\overline{KCD} = \frac{1}{2}\ \overline{CAD} = \frac{1}{2}\ (\overline{CAB} - \overline{DAB})$, $\overline{HCG} = \frac{1}{2}\ \overline{CBG} = \frac{1}{2}\ (\overline{ABD} - \overline{ABC})$, $\overline{GCD} = \overline{HCK} \pm \overline{KCD} \pm \overline{HCG}$, $\overline{CGD} = 90° \pm \overline{HGC}$, GD = gage. ∴ From triangle CGD; $CD = \dfrac{\sin \overline{CGD} \cdot g}{\sin GCD}$. Similarly chords CE, EF and FD may be found.

5. Compute value of CF from triangles ECF and DCF to check the work.

Case 3.—Crossing of Two Curved Tracks.—Calculation for the Chord Lengths when the Frog Angles are all known:

$\overline{KCD} = \frac{1}{2}\ (\overline{CAB} - \overline{DAB})$,
$\overline{HCG} = \frac{1}{2}\ (\overline{ABD} - \overline{ABC})$,
$\overline{GCD} = \overline{HCK} \pm \overline{KCD} \pm \overline{HCG}$,
$\overline{CGD} = 90° \pm HGC$,

$GD = \text{gage}; \quad CD = \dfrac{g \cdot \sin \overline{CGD}}{\sin \overline{GCD}}$.

$\overline{SFD} = \frac{1}{2}\ (\overline{ABF} - \overline{ABD})$,
$\overline{LFM} = \frac{1}{2}\ (\overline{DAB} - \overline{FAB})$,
$\overline{MFD} = \overline{LFS} \pm \overline{LFM} \pm \overline{SFD}$,
$\overline{FMD} = 90° \pm \overline{LFM}$,

$DM = \text{gage}; \quad DF = \dfrac{g \cdot \sin \overline{FMD}}{\sin \overline{MFD}}$.

$\overline{LFE} = \frac{1}{2}\ (\overline{EAB} - \overline{FAB})$,
$\overline{SFT} = \frac{1}{2}\ \overline{FBA} - \overline{EBA})$,
$\overline{EFT} = \overline{LFT} \pm \overline{LFE} \pm \overline{SFT}$,
$\overline{ETF} = 90° \pm \overline{SFT}$,

$ET = \text{gage}; \quad EF = \dfrac{g \cdot \sin \overline{ETF}}{\sin \overline{EFT}}$.

$\overline{HCE} = \frac{1}{2}\ (\overline{ABE} - \overline{ABC})$,
$\overline{KCJ} = \frac{1}{2}\ (\overline{CAB} - \overline{EAB})$,
$\overline{JCE} = \overline{HCK} \pm \overline{KCJ} \pm \overline{HCE}$,
$\overline{CJE} = 90° \pm \overline{KCJ}$,

$EJ = \text{gage}; \quad CE = \dfrac{g \cdot \sin \overline{CJE}}{\sin \overline{JCE}}$.

CHAPTER 21.—BRIDGE WORK AND TELEGRAPH WORK.

Bridge Work.

The maintenance and repair of bridges and trestles is, on large roads, usually in charge of a Superintendent of Bridges and Buildings, but it is a matter with which the maintenance of way department is often intimately connected. The superintendent has under him assistant superintendents, inspectors and bridge foremen, all assigned to certain districts. These men make periodical inspection and reports, and should also make a report upon every job of renewal or reconstruction as soon as completed.

On the Atchison, Topeka & Santa Fe Ry. a bridge inspector is appointed by and reports to the General Foreman of Bridges and Buildings on each operating division, and he is a competent and experienced bridge carpenter, selected with regard to his fitness for the work. It is his duty to examine all bridges, trestles, culverts, cattle-guards, stock yards and buildings, taking the main line first and the branches in the order of their importance. He begins about the first of each month, and completes his inspection about the end of the month, making a daily report by mail and sending in his notebook every week to the General Foreman, who examines and signs it, and passes it to the Resident Engineer to be examined and filed. Besides this, an inspection is made in April by the General Foreman, Roadmaster, Resident Engineer and Bridge Inspector, and another in October by the same officers accompanied by the Superintendent, at which time all important repairs and renewals for the coming year are considered and determined upon, and a complete report on the same made to the General Superintendent.

On the Southern Pacific Ry. the Superintendent of Bridges and Buildings makes a personal inspection of all truss bridges at least once a year, and the Assistant Superintendent of Bridges and Buildings twice a year, while every opening must be inspected and reported upon quarterly by a foreman. This latter report is made to the Assistant Superintendent of the division, and must specify, by number, all structures that require renewal within the next quarter, trestles and truss bridges being kept separate. On the Illinois Central Ry. the Assistant Supervisors of Bridges make complete examinations once in three months, and the bridge foremen every month.

The inspector should keep a uniform record of his inspections, entering in a book the date, bridge number, general condition, and noting in detail any defects that require attention. This book may be a copy of the bridge and trestle record, with a blank page for notes. He signs the book at the end of the trip and sends it to the superintendent or to the bridge foreman. In the latter case the foreman takes note of the repairs required, etc., and then forwards the book to the superintendent's office, where it is filed or copied into the permanent bridge record books. The inspector's record should be so complete, clear, and systematic that when the bridge gang starts out its foreman has full details and can arrange to finish up all work at one place at a time, thus avoiding waste of time in traveling to and fro, except, of course, that any emergency work should be attended to

first. Every opening, however small, should be given a number for ease of reference and location.

The inspector usually travels on a hand car, and is accompanied by the bridge foreman of the division and four bridge men who run the car, assist the inspector, and make any minor repairs that are likely to be overlooked later or which require prompt attention. The tools include a brace and bits and two or three ½-in. crank augers, 4½ ft. long, to be used in boring timbers; two ¾-in. octagon steel bars 4 to 5 ft. long, for sounding timbers. One of these has at one end a ball head 3½ ins. diameter for sounding timbers and piles, and the other end is diamond pointed. The other bar has one end like a pinch bar and the other either diamond pointed or flattened to make a scraper blade for removing sap rot, etc. The diamond point is used for sounding rotten portions. In sounding timbers with the ball head, solid timber will give a firm ring, while rotten wood will give a muffled sound. In boring timber to ascertain its condition the holes should always be bored from the bottom of the timber, or in an upward inclined direction, so that water will not lodge in them. For iron work there are required light hammers for testing rivets and light cold chisels for removing rust scale. In testing rivets the rivet head should be struck a smart light blow sideways, the inspector holding his fingers on the same head and plate at the opposite side from which the blow is struck. Loose rivets should be marked with paint at once. Besides these, there should be on the hand car a 50-ft. tape, 2 ft. rule, plumb-bob and line, monkey wrench, small broom for cleaning dirt from corners, etc. There may also be paint pots, brushes and stencils for renewing bridge numbers, unless this work is done at other times by the foremen and bridge gang. The inspector should watch every large structure during the passage of a fast train, noting any undue deflection, swaying or vibration, or any significant movement or sound, and it may be necessary at times to test the deflection under load.

Trestles.—These have usually an average life of 7 to 10 years, the piles being the first part to decay in pile trestles. Where the amount of trestle work on timber structures is comparatively small the bridge foreman may attend to the inspection, but it is usually best to have a regular inspector over the foreman, the inspector being a skilled bridge man, familiar with strains, designs, shop work, field work, timber framing, etc. On roads where there are many trestles, especially where damp and marshy conditions tend to induce decay, constant inspection and frequent repair must be made to keep the road in safe condition. In addition to the more or less frequent examinations there should be an annual or semi-annual inspection in which the alinement and settling are noted, also vertical positions of bents, conditions of all piles, timbers, foundations, joints, tenons, braces, etc., should be thoroughly looked to, especially where they cross or are framed, the timbers being bored when necessary to ascertain the condition, and a written report should be made as to each bridge, and the report accompanied by a record of the principal members, special marks indicating whether they will require renewal in 3, 6, 9 or 12 months, or are safe for more than a year. On large trestles the bents may be numbered. Mudsills are sometimes laid in open trenches, sheathed with planking, but if buried, the mudsills, feet of posts, etc., should have the earth dug out from

around them for a depth of 18 to 20 ins., so that they may be inspected for dry rot and sounded, and all sap rot should be scraped away to see how much good timber is left. Boring holes in suspicious looking places, especially near the bridge seats and caps, and at the ends of stringers and braces, will reveal the condition of the timber. The alinement, level or settlement should be observed, as also whether the bents are plumb, and if the ends are firmly supported by the banks. The sway bracing should be well bolted or spiked. The floor system should be examined as to to its condition and to see if the stringers have full bearing on the caps and the caps on the piles; also that the full number of bolts, nuts and washers are in position.

Wooden Bridges.—In inspecting Howe truss bridges it should be seen that the trusses have the proper camber, and are vertical, that the chord bolts are snug and the lateral rods properly adjusted. Then the truss rods should be adjusted until the counterbraces have a firm bearing on the angle blocks, and all the rods have the same tension. The timbers, seats, and joints should be carefully examined for cracks, splits or rot. Whenever splices exist in bottom chords, and principally in long span bridges, where they generally occur in every panel, it is important to examine them thoroughly, and to note if they are pulling apart, which would indicate a weakness or a defective clamp. The braces and counterbraces should always have a square and even bearing upon the angle blocks, and the sliding away from their true position, if any, would be sure evidence that the bridge needs immediate adjustment. Such adjustment should never be attempted by the foreman, but only under the personal inspection of the Superintendent of Bridges and Railways, or his assistant. Wooden bridges should be whitewashed inside and outside twice a year. It is well to replace timber stringers of short spans with short plate girders or a solid floor of old rails, reducing the work of the bridge men and the danger from fire, besides making the track more uniform.

Iron Bridges.—All pedestals, bed plates, rollers and their frames must be examined carefully. The bed plates should be perfectly level; the rollers clean and free to move, and their axes should always be kept at a right angle to the line of the bridge. The pedestals should be free from all cracks and flaws, and have a uniform bearing upon all the rollers or upon the bed plate at the fixed end.

In the main trusses all the tension members must be closely examined, also the rods and bottom chords, especially where they are composed of more than one member. If in perfect condition all the members in any one panel should have an equal strain, and when they have not, so that one member is slack and the other tight, the case should be reported at once. The compression members, such as the posts and top chords, should be straight, without a bend or bulge, and all the joints should bear closely against each other. The laterals and counter rods should be tested by shaking them, and they ought never to be allowed to hang loose, but they must not be adjusted while a load is upon the bridge, and they must be tightened only just enough to get a good bearing, so as not to put heavy strains upon them.

All hangers, by which floor beams or stringers are suspended, must constantly receive close attention. Their bearing around the pins should al-

ways be equal and uniform over half the circumference of the latter. If the hangers are made of round or square iron they must be examined with great care in the semi-circle where they are bent around the pins, and where flaws or fractures are most likely to occur. It is of the utmost importance that the nuts on the end of such hangers supporting the whole floor of the bridge should never be permitted to become loose. They should have the threads checked to prevent loosening, and a white streak painted across the face of the nut and its bearing will make it easy to detect at once any motion in the nut. This plan may also be applied to bridge pins, and these pins should be examined for signs of rust, wear or bending. The places where stringers are riveted or otherwise fastened to the floor beams, and which are generally not easy of access for inspection, on account of the wooden floor over them, must be frequently and thoroughly examined, as here the rivets are most likely to get loose, and the webs and flanges of the beams and stringers are more liable to fail from shearing or crushing than anywhere else. The lateral systems and sway bracing must never be neglected when a bridge is inspected. All the rods should be tight but not overstrained, as the struts are liable to be crippled if too much power is used in adjusting the tension members.

Cast-iron parts of all bridges, more particularly when in top chords or in joint boxes, must be closely examined. Should any cracks or breaks be discovered the fact must be at once reported. A ¼-in. hole drilled at the end of a crack will frequently stop its extending further.

Riveted work should frequently be sounded with a hammer to detect loose rivets; and if they cannot be tightened at once they must be marked, and their number and location reported on the monthly report.

Painted work must be examined for indications of rust underneath. No water must be allowed to collect in the interior of any cast or wrought iron parts; drain holes should be kept open for that purpose, and must be provided if they do not exist. The wooden floor system must also be examined.

In addition to the inspection of the structures themselves (whether of wood or iron), the masonry of abutments and piers should be examined for signs of settlement, bulging or tilting; foundations looked to, and soundings taken to ascertain if there are signs of scour around piling, piers, or abutments. Pedestal stones should be examined for signs of cracking or crushing, and it should be noted if the masonry requires painting. It should also be observed if the bridge watchmen and section men keep the ballast back from the abutments, and keep grass, weeds and rubbish cleared away from wooden structures.

It should be borne in mind that old timber taken out in repairs and renewals is not necessarily waste or useless timber, but may be made available in other repair work, and the timber and ironwork should therefore be carefully piled for examination as to its availability and value. In making renewals with creosoted timber, all parts cut for framing, etc., must be saturated with creosoted oil by repeated applications, and then well daubed with hot pitch, this being done as soon as the stick is cut. Every gang using such timber should have a supply of oil and pitch and a 10-gallon pot for heating it. As a rule it is best to have one main yard for timber and piles and to keep only emergency stocks of timber on the divisions.

In bridge repair or renewals on double track the tracks may be gantletted along the middle of the structure, thus giving more room for working on the trusses. To prevent accidents, fixed danger signals should be placed at each end of the gantletted track, and no train be allowed to pass over the gantlet unless the pilotman assigned to that duty is on the engine.

The painting of bridges cannot be dealt with here, but mention may be made of the rules for repainting given by Mr. W. G. Berg in his excellent paper on "Painting Iron Railway Bridges," in "Engineering News," New York, June 6, 1895. Railway companies should, as far as possible, control the purchase of the raw supplies and superintend the mixing of the paint by their own men, by hand or by a small mixer, thus being able to insure that the best pigments and oil are used. Of course, this is not possible if patent ready-mixed paints are used. All work in the field, painting new bridges or repainting old structures, should be done under inspection by the railway company's men, never by contract. For new work, use a priming coat of pure, finely ground, dry red lead, toned down with lampblack, and mixed with pure, raw linseed oil, adding as little drier as possible. The finishing coats to be any suitable paint, preferably dark colored, providing the quality of the pigment is not injurious and the linseed oil is pure. If a cheap paint is required, use oxide of iron paint, bought in powder form and toned down with lampblack, in preference to using cheap ready-mixed paints. For repainting old work, first remove all dirt, grease, rust and old scaling or soft paint, then if the work is in bad condition use a red lead primer coat, followed by finishing coats as above, or if it is in fair condition touch up the bare spots with a preliminary extra coat, and then apply the finishing coat. Paint should not be applied when the iron is wet or the weather cold. Mr. A. J. Swift, Chief Engineer of the Delaware & Hudson Ry., deduced a rule for painting iron structures, giving ⅝-gallon of paint per ton of iron for the first coat, and ⅜-gallon for the second coat.

Telegraph Work.

As a rule the telegraph line of a railway is built by the telegraph company in whose district the railway lies, under contract with the railway company, but the supervision and maintenance come more or less under the charge of the track department. In locating the line, care should be taken to avoid sharp curves and sharp changes of grade where possible, and also to locate it so that snow slides, falls of rock, etc., will not be likely to interfere with it. In cases where heavy storms prevail from one direction the line should be built on the windward or "opposite" side of the track, so that if the poles are blown down they will fall away from instead of upon the track. Failure to observe this has been the cause of much trouble on many railways. There is great danger to trains from telegraph poles falling or being blown down upon the track, and this is especially the case where tall poles carrying many wires are used. For this reason the poles should be thoroughly inspected, and periodically tested by boring (and the condition noted in each case, every pole being numbered); they should also be well braced and guyed when showing signs of weakness, and should be reset when loose or renewed when decayed. The section foremen should know which is the division wire, and repair that first when the wires are

down. Wires that are down should be strung on the fence or got out of the way of the track, and prompt report made to the superintendent, so that the linemen or telegraph repair gang may be notified at once. The foremen should understand the imperative necessity of keeping communication open over the wires, and attending promptly to any defect or breakage.

The poles are usually spaced 176 ft. apart, or 30 poles to the mile; sometimes 150 ft. apart, or about 35 to the mile. They are of chestnut, red or white cedar, cypress, redwood, spruce, Oregon pine or Norway pine, the latter being usually for very high poles. They should be of the best quality of live green wood, with the butt cut above the ground line of the tree, reasonably straight, thoroughly seasoned, and should be peeled and have the knots trimmed close. If painted or set in the ground when green, dry rot is sure to set in. For single poles the diameter should be not less than 7 ins., and 20-ft. poles should be about 10 ins. diameter at 6 ft. from the butt. The butt is sometimes charred, or coated with tar or creosote to a point above the ground line, or tarred in a belt at the ground line. The earth should be well tamped around the poles, but not heaped up into a mound at the base, although a small pile of clean gravel or broken stone will keep weeds away from the base of the pole. Treating one end of the pole is usually not of much practical use, but in Europe the poles are very generally treated with creosote, chloride of zinc and other preservatives, with very satisfactory results, such poles lasting from 25 to 35 years. Creosoted poles are commonly used in English telegraph work, and have been tried in this country, where they have been found in perfect condition, even at the butts, after 12 or 15 years' service. Creosoted poles are better insulators than untreated wooden poles, but are very inflammable, which is one reason for their not being used more extensively for railway telegraph lines in this country. Iron poles are sometimes used, but are dangerous, as they are grounded conductors and likely to cause accidents to the lines and linemen.

The poles should be as low as possible, the minimum headway under the lowest wire being 12 ft. or 22 to 24 ft. at road crossings. In some cases double-pole lines are built, the poles being inclined to meet at the top, or vertical, and connected by the cross-arms. On curves the poles should be inclined to resist the pull of the wire, and poles on curves and in exposed places where high winds prevail should be supported by braces or by wire guys secured to anchors buried in the ground.

The cross arms are usually of pine or spruce, 3 × 4 ins., painted. Those for four wires or less should be secured by two ½-in. lag screws, 6 ins. long, with washers, while longer arms should be secured by a ⅝-in. bolt and two galvanized iron braces. The arms are set into notches or gains in the poles, these gains being from 1 to 3 ins. deep. The insulator pins are either of wood or steel. The former are usually locust, boiled in paraffin oil, driven into holes in the cross-arms and secured by sixpenny galvanized wire nails. The latter are about ½-in. diameter, with a collar resting on the top of the cross-arm. The lower part of the pin is secured by a nut under the arm, and the upper part has a wooden sleeve fitting the insulator. The insulators are usually of glass, although in Europe porcelain is generally used. The middle pins are 22 ins. apart, c. to c.: the outer ones, 4 ins. from the end of the arm, and intermediate arms, 16 ins. c. to c.

The wire is usually of copper or No. 6 or No. 8 galvanized iron, and the joints should be soldered. The sag should not be less than 24 ins. between poles, as a short sag puts a heavy strain on the wire, which strain may be calculated by the following formula, in which A = strain in pounds, B = ½ distance between poles, in feet, C = sag, in feet, D = weight of 1 ft. of wire:

$$A = \frac{B_2}{2C} \times D.$$

The proper sag can be determined by sighting over the cross arms, which are 2 ft. apart.

The following are the official instructions issued by the Western Union Telegraph Co., in reference to the construction, reconstruction and repair of its lines:

Rules for Telegraph Work.

The minimum depth that poles should be set beneath the surface of the ground is as follows (except where rock is encountered, in which case it is only necessary to set 25-ft. poles 4 ft. and 30-ft. poles 4½ ft. in depth):

25-ft. poles	5 ft. deep.	45-ft. poles	6½ ft. deep.
30-ft. "	5½ " "	50-ft. "	7 " "
35-ft. "	5½ " "	55-ft. "	7 " "
40-ft. "	6 " "	60-ft. "	8 " "

In building a line the tops of the poles should be made wedge shape, so that they will completely shed rain or snow. The bottom of the wedge should be 4 ins. above the top of the upper gain. The direction of the wedge must be in a line parallel with the wires and at a right angle to the cross arms.

The slant of poles on curves should be gradual, so that the strain on the poles will be evenly distributed. All sharp curves and angles should be well braced or anchored. Braces are preferable where there is room and suitable timber is available.

Braces should be set a uniform distance from the butt of the pole, at least 6 ft. when possible, and the top of the brace should be just below the bottom gain.

Anchors should be so constructed that the top of the anchor will project a sufficient distance above the surface of the ground to admit of properly attaching the guy wire to the same. Under no circumstances should the guy wire be fastened to the anchor beneath the surface of the ground.

Office poles should be guyed in such a manner as to keep the strain of the wires off the office fixtures and front of building.

Lightning conductors of ordinary line wire will be placed upon every fifth pole on new lines when being constructed, unless otherwise ordered. About 10 ft. of this wire should be formed into a flat coil and placed under the butt end of the pole; the other end of the wire to be stretched up the side of the pole and fastened to the same by 12 or more wire staples, and extended about 3 ins. above the top of the pole; on bracket lines the ground wire should be attached to the pole one-quarter of the way around from the bracket, so that if a second wire is put upon the opposite side, neither of the line wires can touch the ground wire if detached from the brackets. On cross-arm lines the ground wire should be attached to the pole on the opposite side to the cross arm.

Lightning conductors should be attached to all office poles, and when they are placed upon poles already standing, the above directions should be followed as nearly as possible, the coil of wire being placed at least 3 ft. beneath the surface of the ground.

Gains for cross arms should not exceed ¾ in. in depth in sawed redwood poles, nor 1¼ ins. in round cedar poles that are 6 ins. or less in diameter at the top, and in no case should gains be more than 3 ins. in depth in the

largest poles. The distance from the upper side of the top gain to the extreme top of the pole should be 8 ins., and the distance c. to c. between gains must be 2 ft.

When additional cross arms are added to any pole carrying two or more arms, the distance apart must be made to conform to that which may already exist upon such pole. Double cross arms should be used on all office poles, corners, and at all railway or river crossings, and on all unusually long sections. Cross arms will be fitted with sufficient steel pins to accommodate only the wires already on the line, or additional wires that are to be immediately constructed. Two bolts will be used in all cross arms.

When building a line, the cross arms should be faced alternately, first in one direction, and then in the opposite, except when it is necessary to face the cross arms in a certain direction in order to have the arms pull against the pole where bridle or line guys are used.

Cross-arm fixtures should be attached to office buildings with bolts passing through the wall instead of through door or window casing, wherever it is practicable to fasten them in this way. Never use screws for fastening fixtures to buildings, as they are liable to pull out when subjected to a heavy strain.

Wires must be tied on the side of the insulator next to the pole, except on curves or corners, where it may be necessary to place the wire on the opposite side, so that it will draw against the insulator.

The full-sized line wires should be carried to the inside of the building from the standard glass and pin insulators on a cross arm attached to the wall with iron fixtures, in such a manner that the wires will have an upward direction from the insulators to the point where they enter the building, to prevent rain and moisture from following them to the wall. Where the wires run into the building in exposed places, they should be covered with a sloping roof board of sufficient width to perfectly protect them from rain and snow, and should be insulated with rubber tubing where they pass through walls and partitions, using tubing of sufficient length to go entirely through the wall from outside to inside of the building.

Where telegraph offices are located in railway stations, or similar long buildings, the wires should enter such offices at the window or other opening nearest the switchboard, and should be so strung that they can be plainly seen and easily inspected at all times.

At railway crossings all the wires must be kept at a height of not less than 25 ft. above the rails, and at public and private highway crossings not less than 18 ft. above the roadway.

In the construction, reconstruction and general repairs of lines, all splices must be soldered, except on copper wires, where McIntyre sleeves are used. All connections between copper and iron wires must be soldered.

The wires inside of a building should be insulated on porcelain knobs or wooden cleats, and kept as far apart and as far from the ground as possible. The use of staples for attaching office wires is forbidden. Porcelain insulators and knobs must not be used outside of buildings. Rubber hook insulators must not be used outside of buildings, except in places where they are completely protected from rain, snow or moisture, and where it is impracticable to use the standard glass insulation.

All connections in main battery wires must be soldered, and the wires insulated. Permanent terminal ground wires should be composed of No. 8 copper wire, soldered to the main gas or water pipes.

The trimming of ornamental, shade or fruit trees is forbidden, unless the consent of the owner is first secured; then great care should be taken to avoid making the trees appear disfigured. In all cases the brush should be taken away and not be allowed to remain to obstruct the road. Great care should be taken to see that shade and ornamental trees are trimmed early in the season, as it is much easier to get permission to do such trimming before the foliage becomes far advanced.

CHAPTER 22.—GENERAL IMPROVEMENTS.

It will be appropriate here to refer briefly to the larger improvements undertaken to effect a general improvement of a railway, and which will be more or less under the charge of the maintenance of way department. In too many cases questions of cost of operation and maintenance have not been duly considered in the location and construction, and on many lines laid out with a winding and steep location to avoid the first cost of heavy works, and to enable the road to be opened quickly, large sums have since been spent in new work and changes to reduce the operating maintenance expenses. Such work may include the following:

1. Changes in alinement to reduce the curvature.—The Pennsylvania Ry. offers numerous examples of this sort of work, effecting a saving in distance and curvature. This is practically similar to new construction, but care must be taken to properly connect the new and old work where the two locations cross, and to effect the change in track without interfering with the traffic. New banks may be conveniently and rapidly built by dumping from temporary trestles. (See par. No. 10.)

2. Cutting down grades in order to enable heavier trains to be hauled, or to enable the standard trains to pass without having to be divided or to be assisted by pusher engines.—This may be done either by cutting down the summits or filling up the sags. If the filling is of any depth the elevation of rise for new grade should be staked out before beginning work. Taking out sags in grade lines greatly reduces the trouble from couplers breaking and trains parting. (See par. No. 10.)

3. Substituting a tunnel line at low grade for a mountain summit line of high grade.—This has been done on the Northern Pacific Ry. and Great Northern Ry., in the west, and on the New York, Ontario & Western Ry., in the east. The new line is not only shorter, but has easier grades and curves, and is free from the danger, delay and expense incident to the high grade lines, the latter being in many cases switchbacks. Thus the Busk tunnel of the Colorado Midland Ry. saves 7 miles in length, 530 ft. of elevation, and 2,000° of curvature, as compared with the summit line. The Zigzag tunnel line on the N. Y., O. & W. Ry., about 1 mile long, replaces a switchback line with four inclines, about 3 miles long, and saves about $30,000 per annum (formerly expended in helping trains over the summit), or more than thrice the amount of interest on cost of construction of the tunnel. The incline grades were 1.98% for southbound trains, and 1.8% for northbound trains, while on the tunnel line they are 1.25 and 0.75%, respectively.

4. Minor improvements.—These may include the filling up of sags in the grade line (due to settlement of earthwork or bad arrangement of grades) and flattening summits, so as to lessen the trouble from breaking of couplings, due to the jerks and strains caused at such places; and the minor but general changes of curvature to insure a better alinement throughout the length of a railway or a division. These improvements may, perhaps, be undertaken on general principles (if the road considers that the results will warrant the outlay) or to enable the road to compete to better advantage

with rival routes, this latter having been the cause of the extensive work done for the systematic improvement of the Lake Shore & Michigan Southern Ry. A large amount of practical information in regard to widening cuts and banks, operating gravel trains, etc., will be found in Mr. Hermann's book on "Steam Shovels and Steam Shovel Work."

5. Resurveys.—Another and more detailed class of work is the entire resurvey of the line to check its maps, profiles, monuments, land boundaries, etc. In many cases the maps and records are incomplete, especially as to changes in location made during construction (which may affect the actual length and the position of mile posts), and as to subsequent additions and changes in yards and sidetracks, changes in right of way, etc. This work, as carried out on 600 miles of railway, has been fully described by Mr. Hosea Paul in a pamphlet on "Railway Surveys and Resurveys," and in 1896 Mr. George D. Snyder presented to the American Society of Civil Engineers a paper on "The Resurvey of the Williamsport Division of the Philadelphia & Reading Ry." The subject need not, therefore, be further considered here.

6. Filling trestles.—A class of work which is in constant progress on many railways is the filling in of timber trestles with solid banks, providing pipe or masonry culverts for the necessary waterway. The great extent to which timber trestling has been adopted in this country is one of the principal factors in the economy of construction and rapidity of completion which have been characteristic of American railway work, and the use of such temporary structures has been justified by the necessity of keeping the first cost of long lines as low as possible, and by the importance of putting the companies in a position to earn money by carrying freight as soon as possible. Well-built trestles are safe and substantial structures, but all timber structures require frequent attention and repair, and are liable to be destroyed by fire, causing, perhaps, train wrecks and serious interruption to traffic. When once a railway is open, attention should therefore be given to the work of gradually substituting solid banks (with culverts or metal bridges over streams), for timber trestles, as the banks will be permanent and will, under ordinary circumstances, require practically no repair or attention. This work of filling can almost invariably be done much more quickly and cheaply by work trains after the completion of the road than by the ordinary plant used while the road is under construction. In many cases trestles may be filled with material taken out in widening narrow or wet cuts. Two very interesting articles on this subject will be found in "Engineering News," New York, Nov. 28, 1895.

In regard to the construction of earth banks as substitutes for existing trestles, it is often assumed that no particular skill is required or difficulty involved beyond the proper handling of the gravel trains, the idea being that it is simply a case of dumping the earth and keeping the trains out of the way of regular trains. This is doubtless true in many cases where the ground is hard and of an easy slope, but on soft ground or steep slopes the work of filling calls for very careful consideration. In extensive work of this kind on the Canadian Pacific Ry. two specially troublesome kinds of soft bottom were met with. In one case the bottom was practically unfathomable, and swallowed up all the filling until the successful expedient was adopted of using light sawdust instead of heavy gravel for filling. In

the other case, the soft bottom rested upon a sloping rock bed, down which the bank would slide. In some cases the alinement was changed to avoid the most troublesome and dangerous places (and it is to be noted that it was sometimes found possible to get a better location on firm ground than the original location on treacherous ground), but in many cases the difficulties were steadily fought until overcome.

In no case should such work be commenced until careful soundings and investigation have been made as to the depth, slope of hard bottom, etc., and a proper plan then devised in accordance with the conditions to be met. Otherwise the result may be the loss of money, time and material, or the wrecking of a structure and a costly interruption to traffic, as the dumping of material in a swampy bottom or a sinkhole may develop unexpected upheavals in a more or less distant part, which may lead to damage suits or involve the compulsory purchase of real estate. Not only has the foundation to be considered, but also the trestle itself. Thus in the case of a long structure, especially if the longitudinal bracing is deficient, as is too often the case, it is not safe to fill in from the ends or from one end, as the pressure may result in the injury or collapse of the trestle, but the filling must be carried on uniformly along the length of the trestle, thus maintaining a practically horizontal surface for the fill and preventing the straining of the structure. Again, if the earth or gravel is to be plowed off the cars in the usual way, the strength of the trestle is an important consideration in regard to the resistance to the racking strains, and to the lateral strains if a side plow is used, especially if the material is stiff and the cars are chained to the track. A plow being hauled over a car and suddenly striking a boulder or other obstruction may throw very severe strains upon a trestle. This is more particularly the case where the trestle is on a curve. The strains due to plowing off the material may be considerably reduced by using a "rapid unloader," with a steam winding engine on the front car, as described in the chapter on "Ballasting." If there are boulders in the material, an open plank screen, inclined downwards from the edge of the trestle (like an open picket fence) will cause all such large material to fall clear of the trestle bents and form the toe of the bank.

On this work there are many dangers to the laborers, if hand shoveling or hand dump-cars are employed, there being the constant liability of a man falling from or being knocked off the structure. This is especially the case when hand dump-cars are used on high trestles, the floors being usually narrow, and the men likely to stumble, get dizzy or be struck by the moving body of a car. In order to provide against these dangers, however, two or three systems of dumping cars by compressed air have been introduced and used to some extent. The principle consists in attaching to the bottom of the pivoted body of the car the piston rod of a cylinder, connected by a train-pipe and hose couplings with the air reservoir on the engine.

A very effective and economical method of filling where water is obtainable under considerable head is that of washing earth into place from the hillside above the trestle, using a water jet from a monitor in the same way as in placer mining. This method has been employed on the Canadian Pacific Ry. and Northern Pacific Ry. To prevent the water from flowing away too rapidly over the fill, carrying away with it the earth

brought down, and also washing channels in the side of the fill, a bank 6 to 12 ins. high, of earth mixed with hay and straw, or a line of old ties, is placed along the edge of the fill, the earth being deposited behind it and the water flowing over the top. The bank is renewed on the slope as fast as the filling reaches the top. The water and earth are carried down to the fill by a flume, the lower end of which is movable, and the flow from the mouth of the flume can be directed to any desired part of the fill by the use of movable flashboards or guideplanks, set on edge. Such work has been done at a cost of 5 to 7½ cts. per cu. yd. of material in the bank.

The timberwork of the trestle itself remains in place in the bank, but the floor system (consisting of the ties and stringers) is taken out. On the Canadian Pacific Ry. the practice is to fill up to the level of the tops of the ties in the autumn of one year, and then in the spring of the next year, after the frost is out of the ground, the ties and stringers are removed, and those that are sound are used in repairing old trestles.

7. Change of gage.—This is sometimes required on narrow gage lines, especially when acquired by main line connections, and has been referred to in Chapter 18, "Gage, Grades and Curves."

8. Culverts.—Many roads are gradually building new and better culverts, or replacing open culverts having wooden or iron stringers, with short plate girders, having either open floors with ties about 2 ins. apart, or solid floors of old rails or other construction.

9. Drainage.—This may include cutting down and draining slopes to prevent landslides, widening cuts to prevent trouble from snow or from wet sliding banks, the material thus taken out being applied to advantage in filling trestles. Where cuts give trouble from sliding in wet weather, which is common where cuts have been made as narrow as possible to save expense in first construction, and where consequently a very little sliding threatens interference with traffic, it will often be economy to put in a steam shovel and widen the cut to more suitable dimensions, using the material for filling trestles or widening narrow banks. An effort should be made to convince the higher officers of the true economy resulting from such expenditures.

10. Double tracking.—In widening banks the original surface should be thoroughly cleared, as in new work, a trench cut to give a true bearing to the new slope, and the slope of the old bank stepped or benched to prevent separation of the old and new earthwork. The ballasting can be distributed by side dump cars or a side plow, and leveled by a ballast spreader working on the existing track, as described under "Ballasting." Improvements in alinement and grade very generally go hand in hand with the work of double tracking. The Chicago & Northwestern Ry. in 1896 double tracked its line between Madison and Baraboo, Wis., 37 miles, improving the profile for 60% of the distance. Summits were cut down 6 to 10 ft. and intervening sags correspondingly raised, with the result of materially increasing the hauling capacity of the locomotives. Some heavy curves were also taken out. New banks on the realinement were built by dumping material from temporary trestles, the gravel trains being plowed off by "rapid unloaders" hauling side or center plows as required.

11. Elevation of tracks.—In many cases where railways have been built

on the street grades, the dangers and inconveniences to train service and pedestrians caused by the numerous grade crossings have led to the elevation or depression of the tracks at great expense. This work calls for very careful organization and management to keep the cost as low as possible and to avoid accidents or interference with traffic.

Ballast and Work Trains.

A work train is usually given train orders authorizing it to occupy a specified portion of the track as an extra, and no other irregular train should then be authorized to pass over that portion of the track without provision for passing the work train. If it is anticipated that a work train may be where it cannot be reached for meeting or passing orders, it may be directed to report for orders at a given time and place.

Much expense and delay in work done by ballast, gravel or construction trains is frequently caused by considering these trains as belonging to the very lowest class, and allowing train dispatchers to side track and lay them aside at any and all times and places, only occupying the main track by special order, after every other train has had right of way. This causes much loss of time in waiting, besides which the steam-shovel or gravel pit crew and the unloading gang are idle when the train is waiting for regular trains which are behind time. This makes the excavating and ballasting very expensive, and might, in many cases, be easily remedied by the dispatcher if made to understand that the gravel train is an important and expensive item in the maintenance account and should be kept at work to its fullest capacity. Where regular ballasting is in progress at some distance from a station, a temporary telegraph station or bell-code station may be established at the gravel pit, and the men in charge of the train kept informed as to train movements. The roadmaster or other officer in charge should see that the trains are unloaded as quickly as possible, the rails properly cleared and ballast leveled off so as not to strike car steps, brake beams, etc., and the train then promptly sent back or got out of the way. It is generally advisable to keep one train of cars in the pit while the other is out on the track.

It is also poor economy and bad practice to assign old and worn out locomotives to the work trains. The engine may be a passenger engine that is somewhat too old for its service, but still in fair condition and not too light. The caboose, supply car, and regular train of service cars should be equipped with air-brake and air-whistle, and whenever going to a considerable distance the train should be qualified to run as a section of a passenger train with perfect safety. Much time is lost by work trains going to and from work, and in passing over the road for any considerable distance during the day, when taking their chance with the other traffic, as is the common practice.

In the raising of the grade of the New York, New Haven & Hartford Ry. for about 4½ miles at Forest Hills, near Boston, Mass., the earthwork filling was done from the temporary main line double track trestle between the masonry walls. The filling material was obtained from a gravel pit 13 miles distant, and the gravel train service was very carefully organized. Small dump cars were at first tried, but gave much trouble by getting derailed, and flat cars used were found to be unsatisfactory by

reason of the time occupied in unloading them. As finally organized the train consisted of 20 eight-wheel Pratt dump cars of 25 cu. yds. capacity each, or 500 cu. yds. per train. The train was hauled by a powerful mogul engine. There were about 1,000,000 cu. yds. of filling altogether, and the work went on at the rate of about 13,000 cu. yds. per week, or 60,000 per month. One shovel was usually employed, loading one train while another was on the work, but another shovel was put in service if the first could not keep the trains supplied. This work went on night and day. With two shovels at work, 3,500 cu. yds. (or seven train loads) have been dumped in 24 hours. The unloading was attended to by groups of men on the track, who also attended to the ballasting, lining, surfacing and general work on the track. The dump cars were of the design patented by Mr. E. E. Pratt, Superintendent of Buildings of the N. Y., N. H. & H. Ry., and built by the company. They were 28 ft. long inside, rated at 60,000 lbs. carrying capacity, and weighing 25,100 to 25,650 lbs. empty. The sides are made in two parts, divided horizontally. When the train stops the upper half of the side of the car is swung up and half the load dumped. The train then moves on a train length and the lower half of the side of each car is swung down, dumping the rest of the load.

If a work train engine is only required to take the men to and from their work, this engine should attend to the distribution of material for the sections, which frequently require such assistance, and if it cannot be so employed it should be turned over to the transportation department from the time of delivering the men at their work to the time of taking them home in the evening. When it is considered that this engine costs about $25 per day, including the crew, it will be readily seen that with a force of laborers costing $25 a day, it increases the cost of every day's labor performed 100%. Hence the practice of running a work train with a small force of laborers is an expensive luxury, and any work train gang composed of less than 50 laborers will make the average rate of each day's labor higher than any contractor would figure on doing work. Of course, there is always work on the railway that cannot be done by contract, and is only possible to reach by use of an engine; but the force of laborers should bear such a proportion to the cost of the engine that the cost of each day's labor is within reason. In many cases the engine can be profitably employed in unloading rails, stringing new rails, moving switches, etc.

The foreman of the construction gang should act as conductor of the train and share the responsibility for the safety of the train with the engineman. A conductor who has nothing to do with the work of the train should not be employed, there being too many opportunities for him to sleep in the caboose, and he will consequently antagonize the foreman, who is particularly interested in and held responsible for a fair day's work. By the foreman acting as conductor he gets a knowledge of the trains that he would not otherwise have, which enables him to arrange his work to better advantage, and especially smaller items of work (which consume so much of the train's time), so that it can be done between the time of certain trains. This conductor must be an expert foreman, qualified in all branches of track work. He should be provided with an assistant foreman, thus enabling him to give more time to the trains than otherwise would be possible, and, if his force is large enough to require it, he should

also be furnished with a timekeeper. He is also responsible for seeing that the cars are in good running order, and must make reports of all track material delivered, and of all delays experienced through not receiving orders promptly. The trains are usually required to be clear of the main track between 5 or 6 a. m. and 7 p. m., and to be sidetracked for the night at a telegraph station.

On the Lehigh Valley Ry. the work train crews are in the roadway department, and each crew consists of an engineman, fireman and three brakemen. These men are selected with great care, and are considered experts, as there is no more important train than the work train, being in the way of all extra trains, and as the traffic is very great the best men are necessary for the most effective working. There is also a man who acts as conductor and foreman, being selected from the roadway force, and having been raised on the division on which he works. He is qualified to do all kinds of construction and repair work in the roadway department, and is required to pass the regular conductor's examination. There is also an assistant foreman, who is a first-class man, and when the force of men numbers more than 40 a timekeeper is assigned to the gang. The floating gangs formerly employed have been taken off, and the work formerly done by them is now done by the work train gang, which is an improvement, as the material for the floating gang was handled by the work train, and this train was often put to a disadvantage in taking the floating gang to and from work. The work train gang may assist the track gangs at times, as in reballasting when waiting between trains. Ties, rails, etc., should be unloaded at suitable points and where needed, so as to avoid rehandling on the right of way as far as possible.

The conductor and dispatcher should work in harmony, the former notifying the dispatcher as to the location of his work, the time it will probably require, and his movements when the work is finished, while the dispatcher should inform the conductor as to expected movements of trains affecting him, especially of expected extras, so that he can report at a telegraph station in time for orders. It too often happens that the work train is tied up by signals put on regular trains to enable the dispatcher to run other trains which could otherwise be run as extras. The limits of the work train should be as short as possible, as the dispatcher can handle it better, and where the track is crooked and traffic is heavy the work trains should not be allowed to work under flag on the time of freight trains. A work train conductor working on limits should not run past telegraph stations on the way to sidings without ascertaining the times of regular trains and whether the dispatcher can assist in any way. On the other hand, dispatchers should be held strictly accountable for delays to work trains.

On the Richmond & Danville Ry. (now the Southern Ry.) under Mr. C. M. Bolton, Chief Engineer, work or gravel trains were run as extras under special orders, with working limits assigned them, and the practice was to assign limits for work trains for each day between certain mile posts, and for them to keep out of the way of all regular trains. When any special work was going on they were allowed to work close up to the limits, and were given special orders against every train up to the time of arriving, if the trains were behind time, but were required to be out of the

way of passenger trains' time and keep out of the way until the passenger train had passed. Where there was specially important work being done by the work or gravel train a telegraph office was opened at that point, and all trains were required to come to a stop before entering the limits assigned to the work train, until given an order to proceed. These orders were rarely given against first class passenger trains.

On the Pennsylvania Ry. work trains are assigned to all main line supervisors and to branch line supervisors where the traffic is heavy enough to warrant it. The work trains are run as extras, and on single track they are handled by the dispatchers so as to give them every opportunity to work without causing delay to their own movements or to regular trains. Working limits are given wherever possible. On the East Tennessee, Virginia & Georgia Ry. (now part of the Southern Ry. system) the work trains got working limits, usually about 40 miles long, from the dispatchers. This order gave them no rights against any schedule trains, but did give them rights to occupy the track between trains when properly protected by red flags in both directions. When it was necessary for the work train to run any distance, running orders were requested of the dispatcher, who then gave the conductor of the work train orders to run his train as a section of a regular train, or as an extra. In such cases he was not supposed to stop along the line to do any work. After reaching his destination, the conductor again procured a work train order which was simply authority to occupy the track under red flag when no schedule trains were due. It will be seen that in this case the orders were strictly in the interest of the Transportation Department, it being considered necessary for the dispatcher to retain control of the track at all times, so that extras, specials, etc., could be properly handled. When the dispatcher appreciated the cost and importance of the work train, and gave orders to run as a section or extra when called upon, there was really no great delay or interference experienced by the work train. On some parts of the road, when the freight business was irregular, the work trains were authorized to occupy the main track under flag until the arrival of freight trains. On the Chicago & Eastern Illinois Ry. it is customary to have an operator at the gravel pit when the steam shovel is working.

CHAPTER 23.—HANDLING AND CLEARING SNOW.

One of the annual difficulties encountered is that of dealing with snow, and keeping the road open during the winter. If a road is carried on an embankment, even a low one, the snow will drift up on the windward side until it is level with the track, and will then blow over and form a drift on the other side, so that it is not difficult to keep the track clear. For this reason it is bad policy to build prairie lines on the surface level, but they should be raised on embankments. Shallow cuts will soon fill if the wind is blowing across them, unless snow fences are built (see "Snow Fences"). In deep cuts there will be greater trouble in getting rid of the

snow, and all cuts may be made less troublesome by widening them and flattening the slopes. In sidehill work the drifts against the bank are likely to be dangerous, especially if the toe is about even with the outer rail, as the side pressure on the plow is likely to cause derailment. Such drifts are also likely to contain earth or sand and are therefore very heavy and dangerous.

Steady falls of light soft snow at a mild temperature are the easiest to deal with if the road has proper equipment, but if the temperature is very low the snow may settle and freeze into a mass, or if the wind is high it may be packed very hard in the drifts. Hard dry snow, whether drifting or packed, is apt to be troublesome by filling up against the rail heads, increasing the liability of the engine wheels to slip and even causing derailment unless flangers are promptly used. The same trouble, but of greater extent results from partial thaw followed by freezing, which causes the formation of solid ice on the roadbed. The worst drifts are formed by heavy falls of dry, hard snow which will form drifts in every place affording a lee side. Where the wind blows through a cut instead of across it the snow will not drift, and in fact a change of wind may clear a cut in which the snow is not packed hard. The weight of snow varies from 12 to 25 or even 30 lbs. per cu. ft., according to its condition, while the heavy masses in snow slides sometimes weigh as much as 45 lbs. The weight in Canada has been given as follows: Freshly fallen snow, 14¼ lbs. per cu. ft.; 24 hours after falling, 8° F., 21¼ lbs.; 72 hours, 30° F., 28.7; but after high winds, which pack it hard, it will weight about 30 lbs. per cu. ft. If the snow in drifts 3 to 7 ft. deep has been partly thawed and refrozen and become very hard packed, the plows may run upon it and be derailed.

Snowsheds are sometimes built in open flat country, but mainly on sidehill lines and to cover deep cuts on mountain divisions, at places where deep drifts occur. They are usually heavy log structures, sometimes with rock-filled cribbing on the up-hill side, earth being filled in behind the cribbing to a level with the roof of the shed so as to form an even slope from the hillside to the outer edge of the shed roof. The bents are 5 to 10 ft. apart, and framed bents of triangular section are often used for the outer or downhill side. Planking is spiked to the batter posts of these bents, a narrow opening for light and air being left along the upper part, under the overhang of the roof. The timbers are usually 8 × 10 to 12 × 12 ins., with 3-in. and 4-in. planking. Some forms of snowsheds used on the Canadian Pacific Ry. are shown in Fig. 220.

On the Canadian Pacific Ry. an open air line is laid outside the snowsheds for use in summer. The sheds must be carefully watched and patrolled, as there is great danger from fire, which, if once well started, is very hard to fight. In some cases, on the Central Pacific Division of the Southern Pacific Ry. (crossing the Sierra Nevada) fire trains, equipped with tanks, fire pumps, hose, etc., are kept in readiness, while some of the important sheds on the Canadian Pacific Ry. have pipe lines, with 200-ft. coils of hose at hydrant nozzles 400 ft. apart. On open hillsides, where snowslides occur, glance and split fences are sometimes used, the former to guide the snow into gullies, and the latter to break up the slide. These latter are V-shaped, with a sharp angle and a strongly braced and anchored crib at the point.

They are used to protect ventilating openings in the sheds, as in heavy weather the smoke escapes slowly, and the shorter each shed is the better. Snow fences have already been described.

In fighting snow there are two methods to be followed. The first is defensive, consisting in the use of snow fences, and the use of pilot or engine plows or plows hauled by the trains, so as to keep the snow from covering the track to such a depth as to interfere with the traffic. The second is aggressive, and consists in the use of bucking plows, snow excavators and armies of shovelers to clear out deep drifts and heavy falls which have blockaded the road. In a heavy storm or a succession of storms, the main

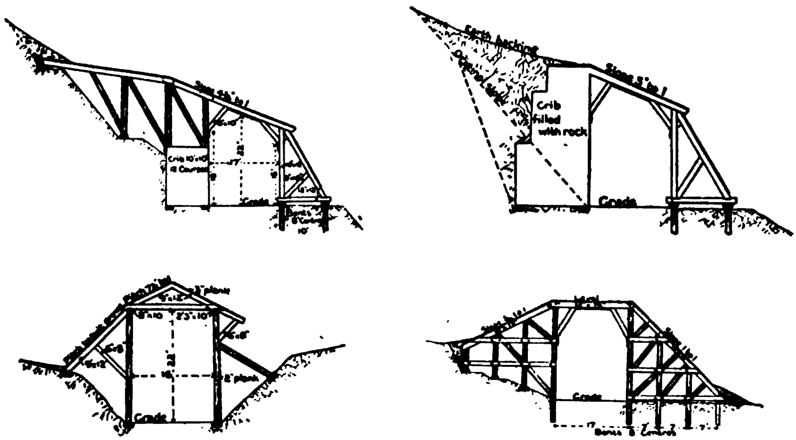


Fig. 220.—Snowsheds; Canadian Pacific Ry.

thing is to keep on breaking up the drifts by snow plows, so that they do not have time to pack and become so hard as to require shoveling, and the work of the breaking plow must be supplemented by the wing plow and flanger to widen the cuts and clear the rails.

The shoveling of snow by hand is slow and laborious work, especially in heavy drifts and with snow still falling or fierce winds blowing. Such work is often attended with danger, and the men in charge should see that the laborers sent out are warmly clad, and that provisions and hot coffee are provided. In shoveling from deep cuts the work must be done in benches, the vertical height of which is the height to which the men can shovel the snow without too much exertion. With shoveling in heavy work there is sometimes difficulty in getting rid of the material, and it has to be carried out on work trains, and dumped over trestles, etc. On one part of the Canadian Pacific Ry., in the winter of 1887-88, after several small structures had been filled the snow trains had to be run considerable distances, entailing great loss of time and constant trouble in backing up over badly flanged track, due to the almost continuous snowfall and drifts in that neighborhood. These difficulties were avoided the next year by the use of the rotary plow and a small gang of shovelers. The compressed slope snow was shoveled onto the track to a width covered by the scoop of the rotary and the wings of the bucking plow, and was thus

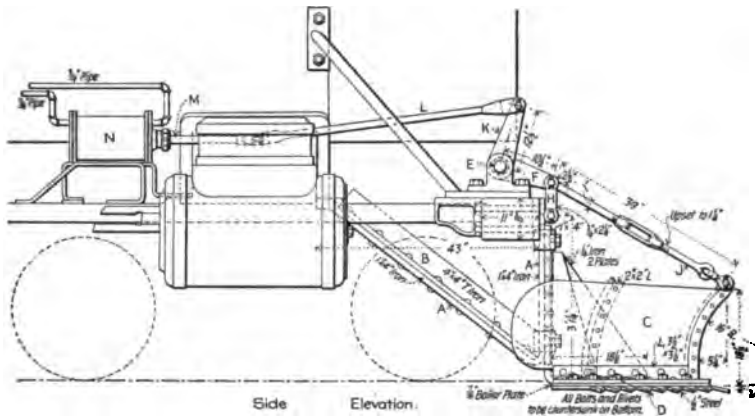
thrown far out and clear of the track, and a good flangeway left. In heavy level snowfalls of over 12 ins. the rotary plow was used, but with less than that the ordinary wing-plow was used, as it could be run faster, and time was of first importance, besides which the wing-plow, of course, cost considerably less in operation. Cuts widened in the way noted above are less liable to fill up again very quickly. Some roads slope the snow cut back for 30 or 50 ft., and the wider the cut the longer it will stay open.

A deep snow cut with vertical sides, as left by the plow, is liable to fill very quickly, and it is wise to break down the sides, shoveling the loose snow into the cut, and then run a plow through at high speed to fling the snow to a distance. If the snow in deep drifts is hard, it is well to cut trenches across it, either large trenches, 30 ft. long and 10 ft. wide, and about 30 ft. apart, or short ones with two men to each trench, the trenches being just as long as the men can work, and 15 ft. apart. This can be done by the regular section gangs as well as the snow shoveling gangs, and this trenching enables a locomotive with engine or bucking plow to easily break through and clear the drift. When men are engaged on this sort of work, or in a narrow snow cut with vertical sides, a man should be posted on top of the cut to watch out for and give warning of the approach of trains or plows.

The section men and yard men must look to the clearing of snow from yards, switches, frogs, crossings, guard rail flangeways, etc. Yards should have plenty of good clean ballast, and be kept well drained, so that in case of a cold snap following a thaw there will be less liability of thawed snow freezing up the switches, etc. The trenches in which switch connecting rods work should be kept open to prevent the accumulation of water which, by freezing, might prevent the operation of the switch. Salt should be used in clearing snow and ice from switches and frogs, and light drifting snow frequently swept out, the slide plates being also frequently oiled as the salt water will rust the iron and make the switch rails hard to move. Where many snowstorms occur during the winter it is a good plan to put up posts near the switches in yards, with a broom and shovel hung on each ready for use.

The use of plows should be commenced as soon as a storm begins, pilot plows being used first. In using a plow the bucking is, of course, done with the plow ahead of the engines, but wing plows should be hauled behind the engines. These plows have hinged flaps or wings on each side, the spread of the wings being controlled by levers or air cylinders operated by a man in the "lookout" in accordance with whistle signals from the leading engine, the wings being, of course, closed in to clear bridges, tunnels, etc. The wings usually spread about 3 ft. beyond the side of the plow. The following plan may be used for clearing snow on lines with two or more tracks: Both tracks are kept clear for the plows. On one track is run an engine with a wedge-shaped, square-nosed bucking plow in front and a wing plow behind. This clears the cut on one side and throws a bank of snow over towards the next track. Following this comes an engine with a side-delivery plow in front and a wing plow behind, with the wing on the outer side of the track extended. This will not only clear its own track but shovel off the snow thrown out by the wing of the first wing plow.

Pilot and Engine Plows.—The use of pilot plows, or snow plows bolted to the engine pilot, is common on most railways which have to deal with moderate or heavy snowfalls, as they serve to keep the track from getting blocked with snow, except in case of very heavy storms or drifts, and enable the train to make better time by clearing the track of light snow. In general these are curved plates rigidly bolted to or in front of the pilot, but Fig. 221 shows an adjustable plow, operated by compressed air from the



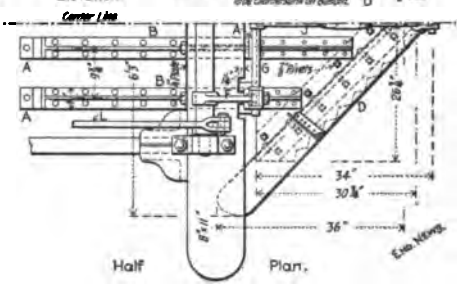


Fig. 221.—Pilot Snow Plow and Flanger; G. R. & I. Ry.

brake reservoir, which was designed by Mr. J. E. Keegan, Master Mechanic of the Grand Rapids & Indiana Ry. This device is locally known as the "go-devil," and has been in use on that road for two winters with satisfactory results.

Four flat bars, A, 1 × 4 ins., are bolted to the bumper beam, and carried down to within 3 ins. of the rail level, being then bent back and inclined upward to have the rear ends attached to the cylinder casting. The inclined part of each bar is stiffened by a 4 × 4-in. tee iron, B, riveted to its upper side. The plow, C, is of the usual form, with overhanging nose and curved wings, extending well forward of the bumper and to a height of 18½ ins. above the rail. The sides are braced by 2 × 2-in. angle irons, and the bottom by 3½ × 3½-in. angle iron. On each side of the bottom is bolted an ice-cutting plow or flanger, D, consisting of a steel plate, ½-in. thick, with notched edges bent down so as to cut the ice and snow along the side of the rail. When in position for work, the ice plow is 3½ ins. below the top of the rail. On the bumper beam are bolted two bearings for a 3-in. rocker

shaft, E, carrying two rocker arms, F, connected by a 1⅝-in. rod, G. To this rod are hung two links, H, by which the heel of the plow is lifted (sliding vertically on the 4 x 1-in. bars, A), and a diagonal rod, J, which lifts the nose of the plow, and which is adjusted by means of a turnbuckle. A third and upright rocker arm, K, on the shaft, E, has a connecting rod, L, to the piston rod, M, of an air cylinder, N, placed behind the steam chest and supplied by a ¾-in. pipe.

The Chicago & Northwestern Ry. has a somewhat similar plow, but with a flanger pivoted to the outer side of each face of the plow, the flangers being raised by an inverted air cylinder behind the plow. Slots allow the flangers to move ahead in rounding curves, the pressure of the snow bringing them back into normal position.

Next to these come the larger engine plows, which are usually of iron, bolted to a special wooden frame which takes the place of the pilot, the plow extending above the top of the boiler and being braced to the frame and smokebox. On the Northern Pacific Ry. snowdrifts up to 4 ft. deep are handled with pilot plows, unless too hard, in which case channels are cut across the track. The snow-bucking plows are of the wedge type, of which there are two designs, one having central deflecting wings, which throw the snow to each side of the track, and the other a single deflecting wing placed diagonally on the wedge portion of the plow and throwing the snow to one side of the track only. This wing is adjustable and used on either side at will. On double track the single-wing plow is found to be most useful. Engine plows of this kind have been used for drifts even up to 15 ft. deep, the drifts having first been cut by cross trenches.

Bucking Plows.—The ordinary form of bucking plow resembles a large box car with a plow-shaped front end, and the pushing power is applied to the rear of the frame. If the plow is run at high speed into a drift it has to stand very severe racking and wrenching strains, and not unfrequently the plow leaves the track. This leads to continual delay in digging out and replacing the plow. If the plow and engines strike a heavy drift the sudden shock is likely to derail both plow and engines, or to shift the tender tanks, or the plow may run up into the snowdrift. Drifts that have been in place for several days should not be bucked until soundings or some investigations have been made, as there may have been alternate thaws and freezing resulting in large and dangerous pockets of hard ice. The plow will only drive a certain distance into the drift, and must then be dug out to enable the engines to haul it back for another run, and sometimes one or more of the engines has also to be dug out.

The dimensions of any plow in cross section should be such as to leave a clearance of 3 to 5 ins. above the rails and 5½ ins. between the plow and fixed structures, such as bridge abutments, tunnel walls, freight platforms. The plows of the New York Central Ry. are 10 ft. 1 in. wide, and 12 ft. 2 ins. high from the ties, the overhanging nose being 9 ft. above the ties. Sometimes the face of the plow is square to the track, but more commonly it is wedge-shaped in plan.

One of the best forms of bucking plows is the Russell snow plow, Fig. 222, which is now extensively used, and which is built by the Ensign Manufacturing Co., of Huntington, W. Va. It is of massive construction, with very heavy framing and lateral bracing, and is mounted on two four-wheel trucks with roller side bearings. It is built for single track, with a central nose di-

viding the inclined plane of the face; or for double track, with a vertical nose at one side, so as to discharge the snow on the right hand side only. The latter plow may also be used for sidehill work. The large plows have on each side an elevator wing, 9 x 11 ft., for use in deep drifts, the wings being forced out so as to widen the cut, and having curved channels by which the snow is delivered above the machine. These, with a slight tapering of the sides back from the front, prevent the snow from wedging or binding against the side of the plow. The pushing timber is of oak, 12 x 12 ins., with its front end let into the oak timber, 12x12 ins., which forms the backbone of the inclined face of the plow, so that the propelling power is applied right at the nose of the plow and not at its rear. This greatly reduces the danger of derailment, and the plow is in practice run up to its work in drifts, 5 to 15 ft. deep, at speeds of 25 to 35 miles per hour. The rear end of this timber is fitted with a heavy coupler head having slots for close coupling to engines of different heights. The pushing timber is not a fixed part of the framing, but has a lateral movement, allowing it a certain

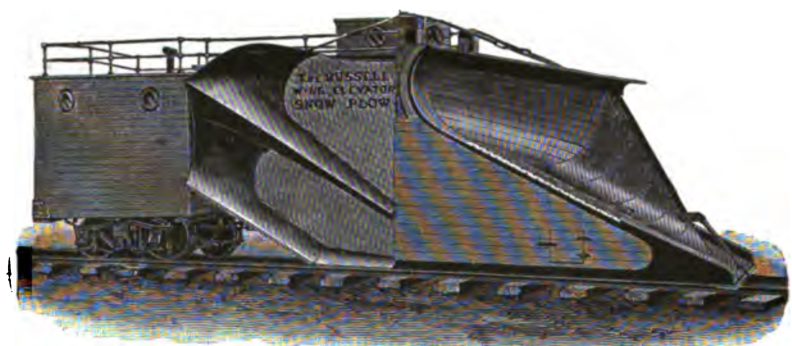


Fig. 222.—The Russell Snow Plow; with Wing Elevators.

amount of play on curves. A coupling bar extends through the face, by means of which the plow can be hauled. The horizontal edge has a sharp steel cutting edge; about 5 ft. back from the edge begins the share, with curved flaring sides to throw off the snow. The sharp cutting edges of the front and sides enable the plow to get into and under the snow, wedging it up and lifting and loosening it before it reaches the share where the side pressure begins. This again tends to reduce any liability to derailment. The front end is covered with a ⅛-in. steel plate, and the double track plow has on the side opposite the run of the share a ⅜-in. steel plate extending the full height of the machine, its front edge forming the vertical cutting edge in advance of the share. In working, a man rides in the cab or outlook and signals the engineman of the pushing engine by a bell cord.

A Russell plow has successfully bucked hard packed snow 6 to 8 ft. deep, using two engines with a run of about ¼ mile, and having a speed of about 30 miles per hour. With one engine it will handle 6 or 7 ft. of snow and go through 4 or 5 ft. of snow for half a mile without stopping. With two engines it will handle 7 to 11 ft. of snow and go through 8 or 9 ft. for ⅛ mile

without stopping. One of these plows with wing elevators, weighing 65,000 lbs. and being 40 ft. long and 11 ft. 8 ins. high, has been used on the New York Central Ry., usually with two mogul engines having cylinders 19 x 26 ins., but sometimes with three lighter engines. Drifts 3 to 9 ft. deep and 200 ft. long, and up to 10 and 15 ft. deep, 300 ft. long, were disposed of, and also a drift of 2,200 ft. long and 3 to 10 ft. deep. The speed was about 30 miles per hour in running at the drifts, or sufficient to go through without stopping. It is claimed that, owing to the construction of the plow, there is no danger of derailment, even in sidehill or diagonal drifts. After the first cut is opened the plow is run through with extended wings to widen the cuts and make a slope instead of a vertical wall.

Snow Excavators.—The first mechanical snow plow or snow excavator in this country was the Leslie or rotary plow, which was built in 1885, and was afterwards purchased by the Union Pacific Ry. It is a large car mounted on two four-wheel trucks and containing a boiler and engine for rotating a vertical wheel 9 ft. diameter in an open-front case on the front of the car. This wheel revolves at high speed in a plane transverse to the track, and is fitted with knives which cut off the face of the drift, delivering the snow behind the wheel into a closed circular box containing a fan which discharges the snow through a movable chute in the top of the box to a distance of sometimes 200 ft. from the track. The wheel can be driven in either direction, having double-edged blades moving on a central pivot. A locomotive boiler is used, and the engines have cylinders 17 x 22 ins., driving the wheel by means of gearing. A flanger is fitted behind the rear truck. The ice cutter and flanger are connected by iron rods to cranks on a balanced shaft, by which they are raised and lowered simultaneously by an air cylinder supplied from the main reservoir. They are operated by levers in the pilot house. The ice cutter and flanger are each held in place by a shearing bolt, which will be broken if an obstruction is struck, thus allowing the blades to swing back and preventing damage to the machinery. The plow is about 28 ft. long over all, and weighs 110,000 lbs. It is built by the Leslie Brothers Manufacturing Co., of Paterson, N. J.

In tests on the Pacific Division of the Canadian Pacific Ry., in the winter of 1888-89, this machine was found to work best in heavy snow, at about 5 miles per hour. If pushed faster it was liable to become choked. With dry snow, either level fall or drifted, it could be run at 15 miles per hour. Even where the character of the snow caused slow work (with one mogul and one consolidation engine pushing the plow down a grade of 2%) a slide of 32 ft. greatest depth, estimated to weigh about 30 lbs. per cu. ft., was cleared in five hours, with only 18 men. Shoveling, with all the men obtainable, would have taken about 12 hours. The machine was considered specially valuable for dealing with heavy snowfalls, deep drifts, and sidehill slope snow-slides. The greatest depth it has worked is 45 ft. The cost of work with one pusher engine is about 17 cts. per mile, or 33½ cts. including the pusher.

The Jull or "cyclone" snow excavator is a large car built on an iron frame mounted on a six-wheel leading truck, and a four-wheel trailing truck, and carries the machinery for driving a huge cone, whose axis is vertically and horizontally diagonal to the track. The cone has its apex at one of the front lower corners of an enclosing frame or housing, while the center of

the base is at the opposite back upper corner. The cone is built of ½-in. steel plate, and is about 7 ft. 8 ins. long, 12 ins. diameter at the apex and 7½ ft. at the base, having upon it four spiral curved cutting blades, making about ¾ of a revolution in the length of the cone, and varying in height from 16 ins. at the axis to 24 ins. at the base. The blades are made of two thicknesses of ⅜-in. steel plate, pressed in dies to the exact shape. These plates flare out and are riveted to the shell of the cone by countersunk rivets. At the front they are nearly straight, but towards the base their curve increases gradually. They are cut away at the base, however, for a width of 24 ins. on the cone, to allow the snow to escape freely. The housing of the cone is 10 ft. 4 ins. wide, 9 ft. 4 ins. high and about 9 ft. deep, the bottom being 3½ ins. above the rail head. The edge of this cuts into and loosens the snow. The cone is revolved at high speed (in one direction only), and the blades carry the snow to the back of the cone, where it is thrown off by centrifugal force through one or other of the adjustable openings, falling at a distance of 40 to 60 ft. from the track. The one appliance thus serves for cutting and discharging, while the "Rotary" requires a cutting wheel and a discharging wheel. The boiler is of 800 HP., and the engine has cylinders 18 x 24 ins., driving the cone shaft by bevel gearing, the ordinary speed being 250 revolutions of the engine and 300 of the cone, per minute. The flanger between the trucks is a V of ½-in. steel plates, 18 ins. deep, with a width of 7 ft. over the broad part. It is mounted on a parallel motion, and is so adjusted that it will swing back and up if it strikes an obstruction. It slides on top of the rail and is raised or lowered by a steam cylinder controlled by a lever in the cab. The entire machine is about 42 ft. long, 15 ft. high to the top of the "lookout" and weighs 130,000 lbs. Its cost is about $15,000. An ordinary locomotive tender is coupled to the rear of the machine, and behind this are the pusher locomotives. The plow is built by the Jull Manufacturing Co., of Brooklyn, N. Y.

In January, 1890, it was run on the Union Pacific Ry., in Wyoming, in drifts 6 to 25 ft. deep, and ½ to 1½ miles long, one long drift having been unbroken for three weeks. While the cone was running at 75 revolutions it struck a cow buried in the drift, cut it in two and threw it out with the snow. In February, 1891, the machine ran over the Pacific Short Line, from Sioux City westward, clearing out the line, most of which had not been in operation for about ten days, and was completely blocked by drifts 8 to 15 and even 20 ft. deep, and in cuts 300 to 2,000 ft. long. In some cases it had to cut through snow and ice with a mixture of sand, frozen hard. It ran at a speed of 6 to 8 miles an hour, throwing the snow right out of the cuts and sometimes beyond the fences.

Flangers.—A most important implement to be used in connection with the snow plow proper is the flanger, which clears the snow and ice away from the rail heads, especially on the inner side, so as to leave an ample flangeway (usually about 5 ins. wide) for the wheels. This device is usually mounted on the snow plow, but sometimes it is fitted to a special flanging car, and operated by hand levers or air cylinders, it being necessarily raised at frogs, switches and crossings, and at road crossings where the planks have not been removed. The Nevens flanger, designed by a roadmaster on the Maine Central Ry., is fitted to a car, and consists of a double-bladed scraper, set diagonally across the track at an angle of about 75°

and resting on the rails. It is connected by chains and rods with the levers in the car, by which it is raised and lowered, and being double-bladed the car can be run in either direction. Each blade consists of a mold board so curved as to throw the snow well away from the track, and a steel knife for cutting the snow and ice. The knive blades cut even with the tops of the rails, 16 ins. wider than the gage, and also cut a groove 2½ ins. deep and 15 ins. wide inside each rail. The mold boards and knives consist of two parts set end to end with a middle vertical joint, and provided with a connecting sleeve and spring which allow the parts to slide upon each other, or jackknife together in case the scraper strikes an obstruction. The scraper can be easily operated by one man and the car can be run at a speed of 30 to 35 miles per hour. One form of flanger for pilot plows is shown in Fig. 221. On the Northern Pacific Ry. two types of these flangers are secured to the pilot and work in combination with a shallow kind of snow plow wing, the flanging knives being secured at front or point of pilot and lifting at rear end only. Another device for flanging is in use on the rotary plows. This flanger is secured to the rear axle of the front truck by means of wrought iron bearings lined with brass, and engaging with the axle near the center of its length. The rear of the flanger is supported by connection with air apparatus, by which it is raised and lowered on an arc, the center of which is the truck axle at its front.

The Priest flanger, designed by Mr. A. F. Priest, Master Mechanic of the Duluth, Missabe & Northern Ry., is in use on a number of railways. It is a flanger only, and not designed for heavy drifts, although an engine will penetrate farther into a drift with one of these flangers than without it, even in a cut where there is no chance to throw the snow out, for the reason that it is lifted, or loosened up, giving the driving wheels a clear flangeway. This flanger goes entirely behind the pilot, supported on the equalizing bars, the cutting thrust being borne entirely by the engine truck box. The object in carrying the cutter bar on the equalizers is to obtain an even depth of cut, which is done by using slotted lifters, so that the cutter bar partakes of none of the vertical motion of the engine on its springs. This feature is designed to give an even depth of cut under all conditions, no matter how rough the track may be. The lateral motion of the bar, on account of its being but little in advance of the axle, is not much greater than that of the wheels, so that good work can be done on sharp curves as well as on tangents, and without touching the rail. The knives are set when fitted up in shop 1 in. above the rail and 1½ in. clear of each side of the rail head. Experience has shown that the clearance on the sides could be increased to 3 ins. and still allow good work. This is accounted for by the top and side formations of snow and ice being unable to remain on top of and against the side of the rail after the removal of the backing which supports it. A good point about this is that torpedoes fastened to the rail in the usual way remain undisturbed by the flangers. This machine cuts a swath 12 ins. wide inside and outside of rail, 1¾ ins. deep inside and ½ in. deep outside. The knives only are liable to injury, all reinforcing bars being carried sufficiently high to clear everything. The knives require simply the manipulation of one bolt in removing them. The flanger is lifted by means of air. It may be put on behind any plow, but on roads having no more than 24 to 36 ins. of snow to contend with a small pilot

plow 20 ins. high at point and up to the bumper beam at the rear is all that is needed. The plow cuts the snow down to the usual height above the rail, and the flanger following does the rest. This is important in giving not only the engine but every wheel in the train a clear rail.

A handy device for dealing with moderate depths of snow on side or main tracks is a flat car fitted with a nose plow and flangers, the car being well weighted, especially at the ends, by car wheels or stone. The Michigan Central Ry. has a car of this kind, being a 60,000-lb. car on rigid-center trucks. The plow is of wood and has a vertical nose and sides, the sides being 8 ft. 4 ins. long and 5 ft. 6½ ins. high. It is hung upon the end of a beam 12 x 14 ins. (above the floor), hinged at the rear end of the car, and raised by two vertical brake cylinders mounted near the front end of the car. The flanger is attached to the heel of the plow. A somewhat similar car on the Pennsylvania Lines has a fixed nose plow 7 ft. 2 ins. wide at the heel, 5 ft. long on the center line, with an angle of about 80°. It is faced with iron like a pilot plow, the height at the nose being 2 ft. 4 ins. Between the trucks is hung the flanger, which resembles the plow but has an angle of 60°. This is hung on the end of two 10 x 5 in. timbers 14 ft. 8 ins. long, set on edge, which form a V, the nose of which is inside the point of the flanger, while the ends butt against the transom in front of the rear truck and are hinged by straps to the intermediate sills. The flanger can be raised by a 10-in. inverted air cylinder, the piston rod of which is connected by a rod with the flanger, the flanger moving vertically in guides held by the lateral bracing.

Wire brushes should be attached to the engine pilot and behind all flangers, so as to clean the top of the rail head.

CHAPTER 24.—WRECKING TRAINS AND OPERATIONS.

The exigencies of railway operation, the impossibility of avoiding accidents, and the necessity of removing train wrecks and repairing washouts, etc., with the least possible delay, so as to keep the road open for traffic, render it necessary for every railway to keep in readiness for immediate use "wrecking trains" equipped with cranes, tools and appliances for clearing the track or building temporary structures. The wrecking train, therefore, is a highly important part of the operating plant of a railway, and upon the proper equipment of the train and the proper organization and handling of the wrecking gang depend in great measure the promptness, efficiency and economy of the work of clearing the track after a train accident, or providing temporary connections at washouts, landslides, etc. It is not sufficient to have a lot of old tools and miscellaneous supplies stored in a tool car, but the equipment must be of good serviceable material, including tools and supplies for every kind of work, and these supplies must be neatly and systematically arranged where they can be got at easily and quickly. One of the most important appliances for the wrecking train is a derrick car or steam crane capable of lifting cars or even engines bodily, thus avoiding the necessity of having to smash up

the wreckage in order to remove it from the track. This steam crane should be able to lift a box car high enough to place it on a flat car, and to swing the box car well clear of the track. The trains should be stationed at divisional points, where men and locomotives are immediately available, and supplies of bridge timbers should also be kept at these points for repairs or temporary structures. The number of these trains and the length of division to which each is allotted, necessarily vary with the importance and the amount of the traffic.

The methods of operation will vary in each case, in accordance with the nature of the accident and the work to be done, but while in case of train wrecks it is generally of the first importance to remove the wreckage as quickly as possible from the track, so that provision can be made to carry on the traffic, this should not be done recklessly by the smashing up and throwing aside of cars or other equipment which may with a little care and clearheadedness be moved aside out of the way for future attention. For this reason the powerful 30 to 40-ton derrick or steam crane is a most economical wrecking tool, although some few roads do all the work by lines and jacks, smashing up freight cars if necessary in order to clear the track, and using small derrick cars only for picking up the wreckage and freight. This, however, is not a commendable practice. Derrick cars may be fitted with hoisting engines, or may have the hauling rope attached to a locomotive, the former being the better plan as a rule. The Chicago, Burlington & Quincy Ry. uses a heavy 40-ft. derrick car having two masts, one operated as a derrick by hand gear, and the other having the rope led down through the floor and between the sills to the rear of the car, the end of the rope having a shackle by which it can be attached to a locomotive.

All parts of the derrick and machinery should be designed with a high factor of safety, to withstand the impact due to sudden heavy shocks. The hoisting tackle should be of chain or wire rope for very heavy weights, and the best quality of pure manila rope for lighter weights. Only iron or steel tackle blocks should be used in lifting. A spring shock-arrester may be attached to the lower tackle block, consisting of a cylindrical case containing a heavy coiled spring carrying the hook bolt to which the load is attached. Steam wrecking machines, Fig. 226, should have sills of plate girders, I-beams or channels, sufficiently deep to give vertical stiffness, and well braced laterally. The frame for the machinery should be of heavy iron or of steel, with the bearings for the movable parts formed in them. The power should consist of at least one pair of reversible engines, coupled together, and the crane may be mounted on a turntable, the boiler, coal bunker and water tank forming the counterbalance to the boom. The machinery should have lifting, lowering and revolving motions, raising and lowering motions for the boom, and self-propelling gear, while provision should be made for revolving the crane in either direction without reversing the engines. Straight booms are usually of I-beams or channels, while curved booms are usually plate girders. To anchor the car while making a side lift, two or more outriggers are used, each consisting of a pair of I-beams, placed below the sills, and so fitted that they may be run out on either side, the outer ends being supported by jacks or blocking. Screw jacks to support the car frame, and rail clamps to hold the car down to the track are also provided. A steel wrecking car used on the Norfolk &

Western Ry. is 22 ft. long and 10 ft. wide, weighing 110,000 lbs. complete. The crane has a range of radius of 14 to 20 ft., and is designed to hoist 50,000 lbs., at 16 ft. radius, either in front or on either side, outriggers being used in the latter case. A useful addition to the machinery of a wrecking car would be a steam capstan (or vertical drum), as used on board ship. This device would be very handy for special hauls when the derrick is under load, and would thus replace specially-rigged hand tackle. A device used for the same purposes is a portable hand hoist or crab, consisting of a drum 7 ins. diameter and 25 ins. long, mounted in a timber frame, as shown in Fig. 223, and having a spur wheel driven by a pinion on the shaft worked by the crank handles.

The crew of a wrecking train should consist of 15 to 20 men, including a wrecking boss. All should have had some experience in this line of work; at least six should be familiar with the use of hydraulic jacks and all kinds of rigging, and two should understand how to splice ropes, make hitches

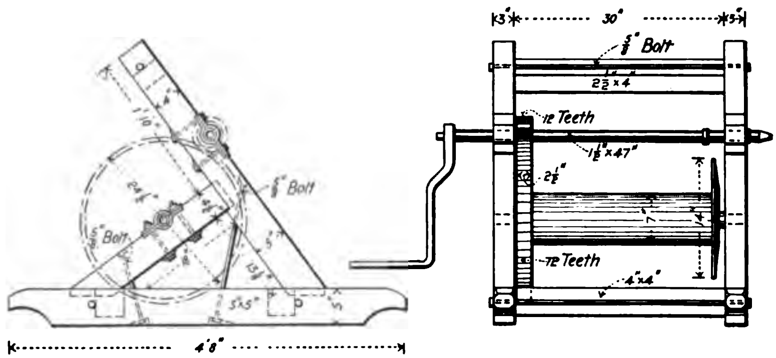


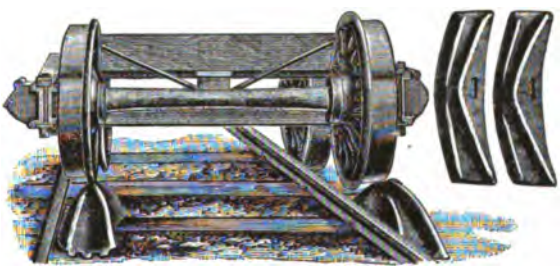
Fig. 223.—Wrecking Crab or Hoist.

and knots of the various kinds, while one should be an engineman, capable of properly handling the engine on the wrecking car. One of the men should be put in charge of the wrecking cars when at the yard, or wherever they are kept, and it should be his duty to see that all rigging is in perfect order for emergencies, and in case a rope, chain, block, jack or any other tool has been broken or damaged at the last wreck, have it repaired or replaced. This man should be a good mechanic and understand how to handle and repair hydraulic jacks and keep them in perfect order. If any of the ropes have been placed in the cars wet or dirty they should be washed off, thoroughly dried, neatly coiled, and placed in their location in the car. All wrenches should be cleaned off, oiled, wiped with waste, and put in their place, as there should be a particular location in the car for each of the tools, and each of them placed there to the end that any of the wrecking crew may go to the car and pick up any tool at once. The man in charge of the car should have a complete list of all tools which belong in the cars, and should proceed immediately after the wreck is cleared to check up his tools, and in case any are missing, report them to the proper superior officer to be replaced.

The tool and living car should have a tool room (with racks for ropes and tools and fixed clamps for jacks), kitchen, office and living room, with berths and table. Steam-heating pipes and a stove should be provided.

In the list of tools and appliances, hydraulic jacks are the most important, being second only to the derrick. A set should include jacks of 10 to 30 tons capacity, and, at least, one pair should be fitted with claws. They should have thumb-screw releases. The common wrecking frog consists of a heavy bent bar, the upper end of which is pivoted to a support which straddles the rail, the feet of this support and the free end of the bar having spurs to bite into the ties or blocking and prevent slipping under a load. With these are used wedges of wood, plated with metal, the "long wedge" being 6 ft. long, with both ends inclined, and the "short wedge" only 3 ft. long, with one end inclined. Various forms of wrecking frogs are used, being placed on or at the side of the rail, as shown in Fig. 224,

Norwood.



Alexander.

Fig. 224.—Wrecking Frogs or Car Replacers.

but probably none of these are superior to the old-fashioned wrecking frog and wedge. The tools of each wrecking car should be painted or marked in a distinctive manner, and one man made responsible for their being returned and kept in place.

Torches and other open lights are a source of danger, especially when there is oil or other highly inflammable material exposed. An electric arc light would add greatly to the convenience and safety of wrecking operations, and it has been suggested that an electric searchlight, mounted on the derrick car, would be specially valuable, as its light could be turned to any desired part of the work. The Pennsylvania Ry. has a car for this purpose, fitted with power for 10 or 12 lamps, the lamps being mounted on tripods 25 ft. high. The poles are carried in a rack on the roof. The car is carried on two four-wheel trucks, with track clamps at the ends of the

frame, and is fitted with an engine, boiler, dynamo and large amount of supplies. This was fully described in "Engineering News," Aug. 23, 1890. On the New York, Pennsylvania & Ohio Ry. a revolving headlight is located on the roof of the derrick car. Two sizes of oil torches are used, the larger ones mounted on wooden posts placed at convenient points, and the smaller ones being carried by hand. The Wells light is an excellent light for wrecking purposes, and is much used. Ordinary hand lanterns are used in working around inflammable wreckage. Where oil is exposed, as in the case of wrecked tank cars, it should be covered with earth or cinders before any work is done around it and before a locomotive or steam derrick is allowed to approach closely. If this cannot be done, a number of empty cars should be coupled between the locomotive and the derrick car, so as to keep the former at a safe distance. Lighting by fires of wood taken from wreck or cars is objectionable, but such fires may be required in inclement weather. The wreck foreman should carry a colored lantern to distinguish him from the rest of the gang.

The conductor's report in case of a wreck, a washout or a burnout should be full and complete. The following is the form used on the Erie Ry., and seems to embrace all the information required. The conductor gives only the letter or number of each question:

....................Station, ...189...

To........................Supt. Time sent.........M. Time received.........M.

Train No. .... Conductor......................

Engine................ Engineer.......................

A. Time and place of accident. (State also if on main or side track, company or individual siding, at frog or switch, in fill, cut, or on level)........................

....

B. What caused it? ....

C. Were any persons injured, and to what extent? Give name, age, residence and occupation, and what was done with the persons?..............................

....

D. Which track is obstructed, and which clear?......................................

E. Which track can be opened first, and how soon?...................................

F. What crossing-switches or sidings, east and west of obstruction, can be used to pass trains around? ....

....

G. How long will it take to get track clear so trains can pass?.....................

H. Will the derrick-car be required, and which way should it be headed to work to advantage? ....

....

I. How much force is wanted to clear the obstruction?...............................

J. Is the track damaged, and to what extent? Have trackmen been notified?..........

....

K. Is engine off track or damaged?..

L. What position is engine in?..

M. What position are cars in?...

N. How many cars broken and off track, loaded? (Give numbers, initials, and kind)....

....

....

O. How many cars broken and off track, empty? (Give numbers, initials and kind)....

....

....

P. How many cars and kinds are wanted to transfer freight in?.......................

Q. What does lading cars consist of? What amount of damage to lading?.............

....

R. How many cars next engine?...

S. How many behind cars wrecked?..

In case of accident the nearest foreman must at once proceed with his whole force to render assistance, even if it is not on his own section, and

if notified of a broken rail on an adjoining section he must at once make the track safe for the passage of trains. When assisting a train delayed by accident the foreman will act under the orders of the conductor (or such other person as the superintendent may designate) until the arrival of the roadmaster or the foreman of the wrecking gang. The roadmaster or supervisor or engineer should proceed at once to the wreck. The foreman must appoint watchmen to protect property at wrecks, etc., and must make a report of every accident, large or small. A natural eagerness to

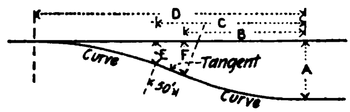


Fig. 225.—Method of Laying Out Temporary Track or "Run-Around" at a Washout or Wreck; Southern Pacific Ry.

get the track clear must not lead to unnecessarily rough or careless handling of cars or freight, or to the destruction of the same. Note should be made of the style, initial or name, and number of all cars destroyed in the wreck or broken up and burned as wreckage.

On double track attention should first be paid to clearing one track. In some cases it may be necessary or advisable to build a temporary track around a wreck or washout, and Fig. 225 shows the standard plan of the Southern Pacific Ry. for such work, the dimensions of the lettered parts being given in Table No. 34:

TABLE NO. 34.—LAYING OUT TEMPORARY TRACKS AROUND WRECKS AND WASHOUTS; SOUTHERN PACIFIC RY.

Ten-Degree Curves.

A ft.	B ft.	C ft.	D ft.	E ft.	F ft.
10	53.6	103.3	156.9	2.5	7.5
20	84.0	133.5	217.5	6.3	13.7
30	107.3	156.5	263.8	10.3	19.7
40	127.3	176.0	303.3	14.4	25.6
50	144.8	193.1	337.9	18.7	31.3
60	160.3	208.3	368.6	23.0	37.0
70	174.5	222.1	396.6	27.4	42.6
80	187.8	235.0	422.8	31.8	48.2
90	200.2	247.0	447.2	36.2	53.8
100	211.9	258.3	470.2	40.7	59.3

Fifteen-Degree Curves.

A ft.	B ft.	C ft.	D ft.	E ft.	F ft.
10	42.2	92.0	134.2	2.3	7.7
20	66.2	115.4	181.6	5.7	14.3
30	85.0	133.7	218.7	9.5	20.5
40	100.8	149.2	250.0	13.5	26.5
50	114.7	162.6	277.3	17.5	32.5
60	127.2	174.4	301.6	21.5	38.3
70	138.7	185.6	324.3	26.0	44.0
80	149.4	195.6	345.0	30.3	49.7
90	159.2	204.8	364.0	34.6	55.4
100	168.5	213.5	382.0	39.0	61.0

If cars are piled up, the top ones should first be removed, and any tilted cars first blocked or upset to prevent their falling over during the

work. A powerful locomotive should be assigned to the wrecking train, especially if it is to be used for hauling on the derrick lines, etc.

The organization of the wrecking force is an important consideration. It is best to have the force in charge of the motive power or operating department than the road department. On the Erie Ry. the train (consisting of a hand derrick, a 25-ton steam derrick and 3 flat-cars) is in charge of a wreck foreman, who is always in the neighborhood during the day, while another man is in charge of the tools and sees that everything is returned to place or accounted for before the car leaves the wreck. This man stays in the neighborhood of the car. The tools are marked distinctively. The wrecking organization is under the division master-mechanic, and car-shop men form the wrecking gang, being better qualified than the section men on account of their familiarity with car work and tools in their daily work, while the same men can always be had for the work, so that they become experienced. At a wreck the work is in entire charge of the wreck-foreman, who alone is held responsible for the proper conduct of the work. Nobody is allowed to interfere with him, and he tells the despatcher just what movements he wants made. For heavy work about 16 men are employed, 2 foremen and 14 men under them, but for ordinary wrecks of two or three cars not more than 10 or 12 men are employed. They are assisted by the section gang as required. With very bad wrecks, one division gets the wrecking gang from the next division. Every baggage car is furnished with an ordinary frog and wedge, and with the necessary chains for doing light wrecking. Jacks, wrecking frogs and wedges are kept at all important telegraph stations and block signal towers, the section foremen being responsible for keeping them in proper condition. By day a whistle signal calls the wrecking gang to the train, and by night there is a system of callers, certain men being called by a man from the station, and in their turn calling others. On the New York, West Shore & Buffalo Ry. the clearing of wrecks is in charge of the roadmaster. The motive power department furnishes four men, one of whom is called the wreck master, and he has charge of the three mechanics sent with him and of the handling of the equipment of the wrecking train. If the wreck is a large one, the master-mechanic is asked to send with the train as many additional shop men as may seem necessary. After the wrecking train is at the point of action, its operation is in charge of the roadmaster, who has collected as many of his foremen and sectionmen as necessary, and either the superintendent or trainmaster is present to assist the roadmaster, but only to assist, as it is believed that only one person at a time can successfully direct the work. There is always an abundance of ideas as to how the work should be done, and if a chance were given to try them all the road might remain blocked indefinitely. Every freight train is furnished with a set of Tilden wrecking frogs.

The quickest way of notifying the wrecking gang is by means of electric bells connecting the despatcher's office with the shops where the men usually work, the men starting for the wrecking train as soon as they hear the bell. Whistle signals may also be given. The despatcher's office may also have connection with electric bells in the houses of the wrecking foreman and of some of the men, so that they can be

promptly notified at night, these men being assigned the duty of calling others in the neighborhood. A telegraph operator should be sent with or soon after the train, unless the foreman is an operator, so that the head office may be communicated with and advised as to the progress of the work. When the force arrives at the wreck the man in charge should organize the men for work and also arrange for the distribution of hot coffee and rations in protracted work, and for the cooking to be properly done. If he sees it will take longer than 12 to 15 hours' work, and he has sufficient force, it should be divided into a night and day gang; the force not at work to be kept entirely away from the work, resting and getting ready for their shift. As soon as the first gang has finished its time, the second should be ready to step in at once and so carry on the work uninterruptedly. If the force is not adequate to be so divided, then there will be much more accomplished if they are worked steadily through the day hours and then required to rest until day again. In this way it is found that much more is accomplished than by trying to push the same men through the night who have worked all day.

In regard to the care and transportation of injured persons, an ordinary car is better than a parlor car, owing to the winding entrance of the latter. Stretchers should be about 7 ft. 3 ins. long and 21 ins. wide.

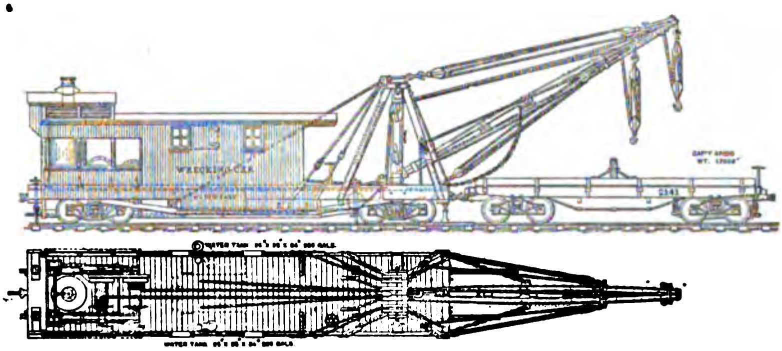


Fig. 226.—Wrecking Car.

The stretchers may be placed across two reversed seat backs, which gives them about the right height for convenient medical attention. In case of cattle train wrecks, the uninjured stock should be transferred promptly, and badly injured cattle must usually be killed on the spot. With refrigerator cars, special care should be taken to replace the ice and put scattered freight back in one of the least injured cars. An interesting paper on wrecking appliance and operations was presented to the New York Railway Club in 1895, by Mr. W. L. Derr, Division Superintendent of the Erie Ry.

As already noted, the equipment and operation vary according to the traffic over the road and the nature of the accident, but from the following particulars of equipment of wrecking train and organization of wrecking gang on several roads, may be obtained a very good idea of the general practice:

Burlington & Missouri River Ry.—On this road the practice is to have

regular wrecking outfits at main points, and also smaller outfits stationed at outside division points at long distances from the main points where regular wrecking outfits are stored. The smaller outfit consists of blocking, jacks, rope, etc., loaded in two box cars that could be got to a wreck promptly and track cleared or constructed around the wreck. Then as soon as possible a regular wrecking outfit is sent out and the wreck picked up with as little loss to property as practicable. The regular wrecking cars consist of a common wooden (oak) mast and boom mounted on a strong car made specially for that purpose. The mast is about 14 ins. in diameter in the center and 37 ft. high above the car bed, pivoted 18 ft. above the rail at the top of a strong stand, so that it can be lowered down and laid on top of the car, together with the boom, when in transit and not in use. The boom is of the same length and size as the mast, except that it is trussed with 1-in. rods on the sides. It is of sufficient length and height to pick up a loaded 34-ft. box car and place it on its truck in front of the derrick. The mast is made from oak piling and has to be renewed occasionally, but the expense of doing this is very small, as selected piling is taken and is fitted up with very little work.

The derrick is provided with heavy base timbers mounted with channel irons, placed on rollers under the car bed in such a way that they can be pulled out and blocks put under the ends, and this with a strong brace from the end of this timber to the top of the mast stand makes the base very wide and firm. When heavy lifting is done, guy lines are run out from the top of the mast to anchors or deadmen in the ground a sufficient distance away for good effect.

The power is derived from one double oscillating engine with cylinders 10 x 12 ins. acting on friction drums and spools with slow and fast motion, as may be desired. The derrick is rated at 35 tons capacity, but heavier loads have often been handled. This derrick enables the gang to take loaded cars that are off the track or have trucks smashed, and set them out on one side, and work right through a wreck and clear the track, setting material to one side without breaking cars or wreckage any more than necessary. Then later on they pick up the stuff and put it back on the track, or load on cars such wreckage as cannot come out on its own wheels.

The plan of organization of the gang is to have the car repairing crews at the main division points organized as a wrecking gang. These men sleep in a car attached to the wrecking train, and are always ready for duty, either during working hours of the day or sleeping hours of the night. The foreman, who sleeps at home, is connected with the despatcher's office by telephone. When the derrick is run out to a wreck, each man gets to his position immediately. The boom and mast are raised, guy lines run out and the work of clearing the track begins. The time taken in getting everything ready is about 20 minutes. There is one man at the engine, one man in front of the drums, and one man at back of the drums to take care of ropes, one man on the deck in front of the derrick to receive signals from the foreman and give them to the engineman by the bell, and two men in the rope car next to the derrick, making seven men in all, besides the foreman. There are no special rules in regard to handling the work, except that if a wreck occurs after regular working hours (which are from 7 a. m. to 6 p. m.), the shop

whistle is blown six times to call the men together in case they should be away from the sleeping car. This is repeated two or three times.

The wrecking train consists of one derrick car, three tool cars, one riding car and one sleeping car. The riding car is used by the men in going to and from wrecks, and to dry their clothing in when wet. The last car in the train is a sleeping car made over from an old passenger car, and has sleeping capacity for 24 men. It has iron bunks (single on one side of car and double bunks on other), steel spring mattresses, wash sink, water closet, and a stove at each end.

Fitchburg Ry.—In the yards at the Boston shops the wrecking train stands on a convenient siding, so that it can be backed out onto the main track with its locomotive headed out of Boston. The train consists of one flat car and two 56-ft. box cars, which were formerly baggage cars, fitted with passenger trucks, air brakes, passenger lamps and steam heat. The flat car has the usual iron crane on its deck, besides two sets of freight car trucks, one locomotive truck, rail benders, rails of various lengths, car replacers, etc. At the side of the track where the train stands are kept two extra freight trucks, so that those used on a trip may be at once replaced on the return of this car. The first box car contains blocking of all sizes, from blocks 12 × 12 ins. to buckets of ½-in. shims. There are also a railway tricycle, picks, axes, saws, and various tools, bushel baskets for gathering up grain, a barrel of sand for use in icy places, shovels for working earth, manure forks, ice tongs, cotton bale hooks, bolts, rail spikes, wooden levers for carrying carboys of acids which cannot be handled, and half a dozen devices called "bee hives," which are truncated pyramids of heavy plank about 4 ft. high and 2 ft. base, to rest a car body on so as to allow of removing the blocking.

The second box car is provided with lengthwise cushioned seats for the men, and contains oil-cloth covers for perishable freight in stormy weather, chains of all sizes and lengths, jacks, bridge tools, oil suits for the men in wet weather, hip boots, etc. The car is fitted with a water closet, a large cooking stove, ice water tank, wash basin with running water and towels. The commissary closet contains canned baked beans, canned salmon, deviled beef, luncheon beef, coffee, tea, a barrel of hard tack, and many kinds of preserved foods. In this car are also a complete telegraph outfit, a tent and poles to protect the operator, several short ladders which can be joined together if necessary, coils of telegraph wire and a rope, a telegraph table, and 36 umbrellas for use in transferring passengers around a wreck in a rain storm. In one corner of this car is a stateroom for the master mechanic, with a berth to let down from the wall; this has a mattress, sheets and pillows, and a rubber blanket to put over the mattress in case a bleeding person should have to be carried on it. Then there are clothes closets full of old clothes, and by using a window and drop-shelf in this stateroom an inside private or public telegraph office can be made out of it. In the rear end of this car there are lanterns, tackle and falls of several sizes, torpedoes and torches, ropes, and boat hooks for getting timbers out of water. The train is equipped with the air signal, and for backing up there is a large warning gong on the rear end of the last car.

There is always an engine with steam up coupled to this train, which

stands just outside the roundhouse. Any available engine is used, and when an engine is thus attached, a card bearing its number is brought into the master mechanic's office and placed in a small holder over the telegraph operator's desk, so that he always knows what engine is there. This enables him to get his train order without delay. The wrecking crew consists of 20 men, and they are at work in the yard, the car shop, the machine shop and the roundhouse. A push-button in the master mechanic's office connects with a compressed air whistle in the car shop, one in the machine shop and another outside. These whistles call the men to the wrecking train, and they are tested every day at 4 p. m. In addition there is a large bell in the roundhouse struck from the master mechanic's office by compressed air at the same time. The bell is used to prevent confusion with locomotive whistling. The code of signals on the bell and whistle is as follows: One stroke and blast—test; two strokes and blasts—any emergency when men are wanted; three strokes and blasts—for a wreck in the limits of the Boston yards; four strokes and blasts—for a wreck out on the road. When these are heard the men come running to the wrecking train. It is the duty of one to get a lump of ice and put it into one of the box cars, of another to attach a

TABLE NO. 35.—EQUIPMENT OF WRECKING TRAIN; NORTHERN PACIFIC RY.

Derrick Car.

1 truck line, 2½ ins. diam., 250 ft. long,	4 iron-bound wedges,
1 truck line, 2½ ins. diam., 200 ft. long,	6 switch chains,
2 second-hand steel rails,	3 truck chains,
	2 wire cables, 1¼ ins. diameter.

Tool Car.

Heating stove,	Picks,
Hand saws,	1 pair of climbers,
Axes,	Scoop shovels,
Adzes,	Pinch bars,
Wheel gage,	Cold chisels,
Steel wrenches,	Clevises,
Soft and chipping hammers,	4 pairs rubber boots,
Track shovels,	Pair patent frogs,
30-in. steel bars,	Iron-bound wedges,
12 torches,	Red flags,
16-ft. ladder,	Red, white and green lanterns,
Assorted sizes drift bolts,	Oil and waste for packing,
Coupling links and pins,	6 baskets (grain), 2-bushel,
8-in. and 12-in. pony jacks,	6 water pails,
Standard frogs,	Standard journal brasses and wedges,
Switch chains,	12 assorted journal brasses for foreign cars,
Torpedoes,	2 hydraulic lifting jacks, 15 and 20 tons,
Portable stretcher,	2 ratchet lifting jacks and levers,
2 gallons alcohol,	A few hundred feet of spare 1-in. to 2½-in. guy lines and snatch blocks,
Packing hooks and spoons,	A small coil of telegraph wire and a few insulators and other telegraph supplies necessary to start an emergency office.
12 grain sacks, 2-bushel,	A full set of edge-tools, the personal property of the foreman of the wrecking crew.
Water barrel.	
Cross-cut saws,	
Hand axes,	
Sledge hammers,	
12 and 15-in. monkey wrenches,	
Spike mauls,	
3-in. rolling line,	

hose (always ready and on a plug near by) and fill the tanks of the box car. Meantime the engineman has got his orders from the despatcher. and as soon as the men are on board the train is off. The rails of the whole siding on which the train stands are kept sanded, so that no time may be lost from driving wheels slipping. Late at night when all of the

wrecking crew are at home excepting the engineman and fireman, this train has been got under way, fully manned, in 22 minutes.

Northern Pacific Ry.—The wrecking outfit on the Minnesota Division consists of a derrick car, tool car, truck car and blocking car, all equipped with air-brakes. The derrick is thoroughly trussed and has a lifting capacity of 20 tons. The truck car carries five freight car trucks of 40,000 lbs. capacity, one engine truck, and two pairs of 33-in. cast iron wheels with standard journals. The blocking car carries a full supply of hard and soft wood blocks, 200 oak wedges, and one small portable building for an emergency telegraph office. The equipment of the other cars is as given in Table No. 35.

The wrecking gang is in charge of the foreman of car repairers, and a regular gang consists of eight men, who have regularly assigned duties

TABLE NO. 36.—EQUIPMENT OF WRECKING TRAIN; PENNSYLVANIA RY.

10 pieces of blocking	7 × 8 ins. × 5 ft. 7 ins.
8 " " "	7 × 8 " × 2 " 9 "
12 " " "	7 × 3¾ " × 1 " 10 "
20 " " "	7 × 8 " × 5 " 7 "
12 boards, hard wood	6 × 1¾ " × 1 " 6 "
12 wedges, hard wood	3½ × 4 " × 1 " 8 "
1 rope, 1¾ ins. diameter	300 ft. long, 2 and 3 sheave blocks.
1 rope, 1¾ ins. diameter	200 ft. long, 2 and 3 sheave blocks.
2 tank ropes, 2½ ins. diameter	60 ft. long.
2 " " 2½ " "	30 " "
2 " " 2 " "	30 " "

4 patent chains,
1 truck chain,
6 dog chains,
8 truck connections,
2 pulling bars,
4 fire buckets,
2 ropes, ¾-in., for fire hooks,
1 snatch block.
2 grappling irons,
2 fulcrums,
1 track gage,
½ coil telegraph wire,
2 large levers,
2 small levers,
8 fire hooks,
1 wooden mallet,
1 ratchet,
2 drills, 1-in.,
2 small vices for splicing wires,
1 pair telegraph climbers,
6 coupling pins,
6 coupling links,
4 coupling links (crooked),
4 body pins, 1¾ ins.,
2 draft pins,
2 short 15-ton jacks.
2 long 15-ton jacks,
2 long 10-ton jacks,
1 broom.
1 dusting brush,
6 oil cans,
6 boxes of matches,
25 signal caps,
150 spikes,
1 fire shovel.
25 three-bushel bags,
10 lbs. waste,
2 patent frogs,
4 pinch bars,
2 claw bars,
1 spike hammer,
2 sledges,
4 jack braces,
4 jack hooks,
1 auger, 2½-in.,
1 " 2-in.,
1 " 1½-in.,
1 " 1¼-in.,
1 " 1-in.,
2 hand saws,
1 axe (hand),
1 soft hammer,
2 iron hammers,
2 monkey wrenches, 14-in.,
2 monkey wrenches, 20-in.,
1 carpenter's chisel, 1-in.,
1 carpenter's chisel, 2-in.,
6 chipping chisels,
2 files, 14-in.,
1 wheel gage,
2 wash basins,
2 pole axes,
6 torches,
8 white globe lamps,
2 red globe lamps,
4 side lamps,
1 sponge hook,
16 clay shovels,
14 coal shovels,
4 spades,
16 picks,
4 cold cutters,
1 soap box,
1 match box.

and are thoroughly organized. When a wreck is reported the foreman is first called; and the caller then calls one of the crew, who in turn calls another and starts for the wrecking outfit. The second man calls

the third and starts for the outfit, and so on until the crew is all on hand. By this system, in emergency, the crew has been on hand 15 minutes after the word was given. Work at night is done with the aid of six large torches, especially adapted to the purpose.

Pennsylvania Ry.—On the Pennsylvania Ry. each division wrecking train is composed of tool car, derrick car, and such maintenance of way flat cars as may be necessary. Single derrick cars have derricks of 5 to 15 tons capacity, while double derrick cars have two 15-ton cranes. The wrecking gangs are in the immediate charge of the conductor of the work train, who, as a rule, is also foreman of the wrecking gang. The supervisor or his assistant is usually in attendance at wrecks of any importance. The custom is to assign men in the gang to handle certain tools, the detail of the work being in charge of the supervisor or the foreman of the gang. The Wells light is used in night work. Table No. 36 gives a list of the equipment of the wrecking trains.

Washouts and Burnouts.

In times of continuous heavy rain, floods and freshets, or in protracted droughts, when there is danger from fire, precautionary measures should be taken by keeping fire tubs and buckets full, clearing snow and drift from all waterways, and by putting on extra watchmen and trackwalkers to look after the safety of structures and watch for indications of undermining of foundations, slips in cuts and washouts in banks. During such times the section foremen and roadmasters should keep the superintendent constantly informed as to the condition of the road, so as to facilitate traffic by preventing delay in running trains cautiously where the road is perfectly safe and by getting prompt attention to any point of danger. After a flood has subsided a special examination should be made of the condition of foundations of abutments, piers, trestle bents, etc., as many accidents occur from the collapse of structures which have been undermined.

Damage to falseworks, timber abutments, temporary trestles, etc., by logs, etc., carried down by the current, may be prevented by a boom of logs on each side of the stream, with the upper end of each boom attached to the shore. These will guide the floating objects safely through the waterway. At trestles, bridges, etc., which are threatened by logs, drift, ice, etc., men should be stationed to guide floating objects through by means of poles, so as to prevent any obstruction. Ice jams or gorges may be shattered and broken up by explosives. A good method is to put about 100 lbs. of blasting powder in a 4-gallon can and sink it through a hole into the water, allowing it to drift some distance under the ice, holding it in position by a rope tied to a stake at the hole. The charge should be exploded by an electric blasting battery, and not by a time fuse.

Washouts can sometimes be prevented by watching, as above advised, but as a rule they occur suddenly and under such conditions as floods, etc., that the only thing to be done is to prepare for repairs at the earliest possible time.

In case of a washout, burnout, wrecked structure, caved-in tunnel, etc., the foreman should first take steps to send out flagmen to stop trains,

and then report at once to the proper track official and superintendent, stating in full the exact location of the accident, the number or name of structure, character and extent of damage, etc., and particulars of train wreck (if any). He should then do what he can with the means at his disposal to prevent further damage, and prepare for the repair work. The wrecking train and gang will then be sent out promptly, equipped with the necessary plant and tools. Further cutting away of the banks of a washout may be checked by covering them with stone, logs, or brush and trees, interlaced to form a mattress, or even by rough cribbing to cut off destructive currents or eddies. It is generally useless to try and fill a gap with anything but stone if a current is flowing through it. If the water is too high or turbulent to allow of commencing the repair work at once, the time may be profitably spent in building trestle bents, cribs, etc., and filling sacks with earth, ready to be put in as soon as possible, as it is of the greatest importance to get the road opened for traffic.

Cribs may be built of old bridge timbers, logs or ties. The latter will be about 8 x 8 ft. in plan, with from two to four ties in each course, and a single crib of this kind will suffice for a height of 6 to 8 ft. For a greater height there should be two cribs side by side, or a wider crib with the two rows of ties transvere to the track, these ties overlapping side by side. The cribs should be brought to a level surface, and topped by regular trestle caps 10 to 16 ft. long, to support the stringers. For wide openings, cribs (with one end pointed to facilitate handling in the current) may be towed or floated out to form foundations for crib or frame pier superstructures, being sunk by stones onto the natural bottom or onto a pile of stone first dumped.

An opening of 15 to 25 ft., with firm sides, such as a washed out culvert, may be spanned by two 12 x 12-in. timbers under each rail (6 ins. apart), resting on a sill at each end. These are crossed by about four smaller timbers carrying two 12 x 12-in. stringers for the rails or ties.

A pile driver is a very important implement where large washouts of banks, trestles or bridges have to be dealt with, and at landslides steam shovels can be used to advantage. The pile-driver car of the Missouri Pacific Ry. is 55 ft. 2 ins. long over the floor, and the leads are carried 16 ft. ahead of the car body, so that 10 ft. panels can be built. It has a reach also of 14 ft. on either side of the track. The leads are 40 ft. long, 20¾ ins. apart in the clear, faced with 8-in. steel channels, and are hung on hinges. A 3,000-lb. hammer is used. The pile handling and hammer lines are led over different sheaves on the leads and over guide pulleys back to separate drums on the engine. The car is fitted with a Mundy engine having two cylinders 7½ x 10 ins., and two 12-in. drums. Steam is supplied by a vertical boiler 45 ins. diameter and 6 ft. high. This car is fitted with two 1½-in. manila hammer lines, and two 1¼-in. pile lines with one end spliced to the ring of a ½-in. crane chain 7 ft. long, the free end of the chain having a hook. Next to the pile car is a flat car equipped with a 20-ton hydraulic jack, 6 screw jacks, 2 snatch blocks for 2-in. line and 2 for 1½-in. line, 3 sets of block and falls for 1-in., 1½-in. and 1¼-in. line, 600 ft. of 1¾-in, rope, hand crab or hoist (Fig. 223). 6 sets of carpenter's tools, and a supply of bars, wrenches, chains. hauling lines, axes, spikes, nails. etc., a supply of coal and a 2,000-gallon water tank. The crew for this car consists of a fireman, engineman and 7 men, or 24 men for emergen-

cles, of whom 8 are laborers and the others bridge men. This crew will drive 5 bents of 4 piles each, cut them off and fit caps, stringers, ties and track in 10 hours.

If a temporary trestle is required, piles may be driven by a pile-driver car, cut off to height and connected by caps drift-bolted in the usual way. If a pile driver is not available, piles or timbers may be put in place singly by a hand derrick, "jumped" and churned by means of ropes to sink them into the bed, and secured to each other by plank braces as soon as they are secure, and using the planks to guide the additional piles. In this latter method the man in charge will not care about getting his piles evenly spaced, but will try to locate them in holes and soft places. Another method, which may be used where there is hard bottom, is to make soundings for each leg of the bent, cut the posts to length, connect them by a drift-bolted cap, and a 4 x 10-in. diagonal brace and 4 x 10-in. horizontal plank at what will be the water line. The bents are then placed in position and connected by longitudinal bracing. If framed bents are used, they are usually of 12 x 10-in. timbers, with four posts secured to a cap and sill by dog irons or plank splices spiked across the joints, and stiffened by two diagonal plank sway braces. The middle posts should be 5 ft. apart, c. to c., and the caps should be 10 ft. long if outer batter posts are used, or 14 to 16 ft. if all the posts are vertical. The bents should be 12 or 14 ft. c. to c. These bents may be floated out to place and swung into place by a derrick or derrick car, or rest upon the bottom or upon a pile of broken stone dumped in place and leveled off. If above the water line or on dry ground the sills may rest upon a mudsill or a row of short cross timbers. Upon these bents may be placed two or three stringers under each rail (two 8 x 16 ins. x 24 ft., or three 7 x 15 ins. x 28 ft.), and track ties laid upon these. The stringers break joints and may be secured by 6 x 6 in. triangular braces or blocks spiked to the caps and stringers.

If the waterway is very wide, rough boats or pontoons may be built for the use of the men engaged in handling piles and bents and putting on the sway bracing. Great care should be taken to insure strong and substantial construction, and ample longitudinal bracing should be provided so as to distribute the pressure and prevent the collapse of the structure by undue pressure upon an unevenly supported bent. In all such work the liability of a second flood or of heavy floating pieces being carried down by the stream must be borne in mind. Mortise and tenon work should not be employed in timbering for falseworks and temporary trestling as it is expensive, takes time, and prevents the use of the timber in other work. The timbers should be butted together, bored, fished and bolted. A handy method of fastening timbers together is by the use of dog irons, 12 ins. long, with the ends bent for 4 ins. to drive into the two pieces, the ends being chisel pointed, one vertically and the other horizontally. One leg is at right angles to the straight front, the other at a little more than a right angle, so as to pull the timbers together. Two dog irons should be driven simultaneously on opposite sides of the joint, so as not to displace the timbers in driving. Where spikes are used they should be ½-in. boat spikes, 8 ins. long.

Roadmasters and bridge foremen should be furnished with a complete list of plans of pile and trestle bridges. and should have blue prints showing the bill of material for from one to thirty panels of bridge deck com-

plete. They should also have a bill of material for frame bents from 8 ft. to 50 ft. in height, showing sway braces and longitudinal and sash girts, and they should have the same for pile bents. They should have a blue print for framing bents, showing length of sills and distance between mortises and length of plumb and batter posts, so that it will not be necessary for them to do any figuring in case of a rush. The foremen in charge of emergency repairs to bridges, etc., should be selected for their judgment and self-reliance as well as skill, since they may often be thrown upon their own resources, owing to the telegraph wires being down.

The following table was prepared by Mr. R. D. McCreary, Engineer of Maintenance of Way of the Western New York & Pennsylvania Ry., and is issued to bridge men, carpenters, etc., to show the necessary width of stringers of different depths for various spans, the spans given being c. to c. of caps or wall plates. The table gives the width in inches of each stringer for fiber strains of 750 and 1,000 lbs. per sq. in. The former is for hemlock or pine structures of one or two spans and where the stringers extend only from cap to cap. The latter is for white oak stringers on single spans and pine or hemlock stringers extending over two spans and breaking joints. The end spans of trestles over two spans in length should be only three-fourths the length of intermediate spans, so as to equalize the stress. The stringers may be of one thickness or divided into two or more members, packed together. The table is calculated for heavy engines, having a weight of 113,800 lbs. on the driving wheels:

TABLE NO. 37.—SAFE WIDTHS OF STRINGERS FOR TEMPORARY RAILWAY TRESTLES.

Span, c. to c. of caps, ft.	Load, bending mom., ft.-lbs.	Width for 12-ins. deep,		Width for 14-ins. deep,		Width for 15 ins.d'p,		Width for 16 ins.d'p,		Width for 18 ins.d'p,		Width for 20 ins.d'p,	
		750 lbs., ins.	1,000 lbs., ins.	750 lbs., ins.	1,000 lbs., ins.	750 lbs., ins.	1,000 lbs., ins.	750 lbs., ins.	1,000 lbs., ins.	750 lbs., ins.	1,000 lbs., ins.	750 lbs., ins.	1,000 lbs., ins.
4	18,730	12.5	9.4	9.2	6.9	7.9	6.0	7.0	5.8	5.6	...	...	...
5	22,910	15.3	11.5	11.2	8.4	9.8	7.3	8.6	6.4	6.8	5.1	5.5	...
6	27,090	18.1	13.5	13.3	9.9	11.6	8.7	10.2	7.6	8.1	6.0	6.5	...
7	31,270	20.8	15.6	15.3	11.5	13.3	10.0	11.7	8.8	9.3	6.9	7.5	5.6
8	35,450	23.6	17.7	17.4	13.0	15.1	11.3	13.3	9.9	10.5	7.9	8.5	6.4
9	42,460	28.3	21.2	20.8	15.7	18.1	13.6	15.9	11.9	12.6	9.4	10.2	7.6
10	50,920	33.9	25.5	24.9	18.7	21.7	16.3	19.1	14.3	15.1	11.3	12.2	9.2
11	59,470	39.6	29.7	29.1	21.8	25.4	19.0	22.3	16.7	17.6	13.2	14.3	10.7
12	70,660	47.1	35.3	34.6	26.0	30.1	22.6	26.5	19.9	20.9	15.7	17.0	12.7
13	82,590	55.1	41.3	40.4	30.3	35.2	26.4	31.0	23.2	24.5	18.4	19.8	14.9
14	94,640	63.1	47.3	46.3	34.8	40.4	30.3	35.7	26.6	28.0	21.0	22.7	17.0
15	106,850	...	...	52.3	39.3	45.6	34.2	40.1	30.1	31.7	23.7	25.6	19.2
16	119,210	...	...	58.4	43.8	50.9	38.1	44.7	33.5	35.6	26.5	28.6	21.5
17	131,730	...	...	...	...	...	...	49.4	37.0	39.0	29.3	31.6	23.7
18	146,050	...	...	...	...	...	...	54.8	41.1	43.3	32.5	35.0	26.3
19	162,050	...	...	...	...	...	...	...	...	...	...	38.9	29.2
20	178,250	...	...	...	...	...	...	...	...	...	...	42.8	32.1

In rebuilding the Pennsylvania Ry., after the severe damage to its line by the flood of May, 1889, the following complete outfit was prepared for feeding and housing the carpenters, telegraph linemen, laborers, etc. Two baggage cars were turned into kitchen and provision cars, and fitted with a cooking stove, tables, benches, etc., and supplied with cooking and table equipment for a strong commissary department. Two passenger cars were turned into dining cars by taking out the seats and building a plank table down the middle for the full length. Day cars were used for temporary sleeping accommodation, each man being provided with two

blankets. A car was loaded with tools and materials for carpenters and trackmen, including two or three 1,000-ft. coils of 1-in. and 1½-in rope, about 50 kegs of 6-in. and 8-in. cut and boat spikes for bracing and scaffolding use, and all the carpenters' tools that could be collected. In addition there were several carloads of 3-in. plank, 12 x 12 or 10 x 10 in. lumber for trestling, standard stringers, etc. While the river was too high and too swift for putting in the trestling, the carpenters were employed in framing caps and top ends of logs. Soundings were taken for the leg of each trestle bent, and about 2½ tons of rails were spiked to the first bent got in position to sink it to the bottom through the current. The bents were 15 ft. centers. The electric lighting car of the Cumberland Valley Ry. (already mentioned) was used.

The course of operations to be pursued under certain conditions has been outlined by Mr. George J. Bishop, of the Chicago, Rock Island & Pacific Ry., in a paper read before the American Association of Superintendents of Bridges and Buildings, 1895, and from this paper the following notes are abstracted:

In making repairs across streams where water is from 10 to 30 ft. deep, and a steam pile driver car is used, the following organization is recommended: 1, Unload enough material to start work; 2, start a gang of men framing ties and one end of stringers and sizing both ends, sizing the end not framed back 30 ins.; 3, start pile driving; 4, have foreman and 10 men in front. By the time the pile driver has a bent of piles driven the foreman has his staging up and height marked on the piles, and at the last blow of the pile-driver hammer the straight edge is put on and two men to each pile start sawing them off. While the men are sawing off the piling the driver has run back for a cap. When the piles are sawed off the pile driver lowers the cap to position and starts for stringers for one side. The stringers are lowered to position and the driver goes back for the other side, during which time the men place stringers and finish drift-bolting the cap. The other stringers are then lowered to position and the pile driver starts for a panel of bridge ties. As soon as bridge ties are lowered the driver goes back for two 30-ft. rails. These are placed on the ties and the driver goes for a pile. It is necessary to use two rails 20 ft. long and two of 10 ft. for temporary work. Rails 30 ft. long do not always work to good advantage on 14 and 16-ft. spans; they are either too short or too long, as the rails should project over the bridge. While the pile driver is gone the track is spiked, bolted, gaged, and lined. There is then, generally, a few minutes' delay of the pile driver waiting for the men to finish. Then it starts driving the next bent. While driving this, two of the men in front are sawing off the ends of the stringers, getting ready for the next panel, and two of the men are detailed to bore and bolt up the stringers, so as to keep everything safe. These operations are continued until the gap is crossed. Of the 10 men that work in front of the pile driver, each man has his part to look after. While the pile driver is driving the next bent, 1 man sees that angle bars, track bolts, drift bolts, and tools are ready for the next bent; 2 men are sawing off stringers; 5 are putting up ledger boards and staging, putting on sway braces and bolting up same; the other 2 men are back boring and bolting up the chord. They should have turnbuckles to pull bents square with the track and to pull the piles into place. All caps are bored out on the dump for sway brace bolts, and the gang there should do all the unloading, framing of material and piling same after framed for the pile driver to pick up. A foreman and 9 men can do this and keep material prepared for a day and a night gang. One man should be detailed from this gang to file cross-cut saws for the pile driver and the two bridge gangs. With proper management, such a gang can drive and complete six to ten panels of bridge work every ten hours, and at night three to five panels of permanent work. As the

night gang has to do all the changing and coaling-up on their own time, there will necessarily be considerable loss of time to them and slower work on account of the darkness. If night work is done it will be necessary to have an extra engine tank for water for pile driver and locomotive. The locomotive should be arranged to take water from the pile-driver tank to avoid running for water from 6 a. m. to 7 p. m., or from 7 p. m. to 7 a. m. In temporary work, where only three piles are driven to the bent, better results can be secured and fewer men are required.

If the pile driver has a reach of 6 to 8 ft., it is well to have two or three pieces of Oregon fir timber 24 x 24 ins., 50 ft. long, and use them as stringers, projecting them over the cap 10 ft. or more and laying bridge ties and track thereon. The driver can be run out on them for driving a bent of piles, and every time one has been driven and capped the stringers can be readily moved forward to drive the next.

There are several different ways of making repairs to banks that have been badly washed at the side. One is to dig down the remaining embankment and bring up the part washed to a level. It is necessary sometimes to make a long run-off, so that grade will not be too steep, as the fill cut down is often 6 or 8 ft. below grade. Another way is to build around the break what is called a "shoofly" (Fig. 225). This is very often done, but it is not advisable except in extreme cases, as the cars are likely to run off the track, or the train to break in two parts on account of sharp curves and steep grades.

The following is recommended as the best way to make these repairs: Where embankments are half washed out and only 10 ft. deep, lay one sill 12 x 16 ins., by 10 ft., longitudinal with track, set plumb posts on that, put caps on the plumb posts, dig out the bank, project the caps through and place stringers under outside rail, resting on caps. The stringers carry the track on one side and the embankment on the other. Where the washout is 18 ft. deep, set up a plumb and a batter post on sills and sway brace the plumb and batter posts to the cap. By putting in this temporary trestle work the track is up to grade, regular trains can be pulled, which cannot be done where the embankment is cut down or a "shoofly" is put in, and it can be filled by work train or steam shovel. If by steam shovel and side plow only a few section men will be required to handle the dirt; on the other hand, if a "shoofly" is put in and filling is done with the steam shovel, it is necessary to scrape dirt off on one side and keep raising track up and throwing in line to get it back on its old centers and grade. This will require a large force of men and will cause a waste of material and delay of shovel unless they have other work in the vicinity. It is the same with embankment cut down, as a large number of men are required.

There should be boarding trains at all large washouts, or other arrangements made for the men to get their meals regularly. This should be looked after by the head of the bridge and building or roadway department, or by some one detailed by him. All bridge gangs should have outfit cars, one bunk, one tool, and one material car, so as to be ready to move upon short notice.

CHAPTER 25.—RECORDS, REPORTS AND INSTRUCTIONS.

Charts and Records.—Most railway companies nowadays keep some form of map or chart record, which shows at a glance the alinement, profile, side tracks, stations, and important features of the roadway equipment. In Fig. 227 is shown a reduced specimen of a graphical chart of the Peninsula Division of the Chicago & Northwestern Ry., the original scales being 1 mile to the inch horizontally, and 100 ft. to the inch vertically. This chart was made for the use of the operating department of the road, and, besides giving a graphical representation and profile of the line, it locates and briefly describes all the truss bridges, roundhouses, turntables, coaling and water stations, and a record of the rails, being intended to include such physical features as pertain especially to the track and operating departments. There is also given in one corner of the sheet a geographical map of the division on a small scale. The charts are corrected once a year and new sets of blue prints are made, which are framed under glass and hung in the office, or cut into strips and folded for the pocket. The sheets are about 34 x 52 ins. inside the border lines.

The top line gives the limits of the track sections, with the number and length of same. The next line gives the miles, a vertical line being ruled across the chart at each mile. Then comes the alinement, with the degree of each curve noted. Below this is shown the geography, the railway being indicated by a straight line, all bridges, road crossings, sidings and spur tracks, buildings, etc., plotted on, and particulars of spans, grades of spurs, capacity of roundhouses, etc., noted. The townships are also marked. Under this is a profile, with bridges marked and described, and elevations and rate of grade in feet per mile also noted. The profile is broken, as required, to keep it below the plan. At the bottom of the chart are shown the make, weight and date of rails, and the length laid with each make. Station and yard tracks are only indicated, reference being made to yard plans, but exterior sidings and spurs are as shown, except that spurs to mines, etc., are not plotted to scale. With each sheet is a table showing the dates of construction from point to point, by years, and another table giving the location of each bridge, its record number, and its clearance in width and height.

A chart used on the Pennsylvania Ry. is 6 ins. high, folding up to a size of 4 x 6 ins., and is divided vertically by sections instead of miles, with the names and addresses of the supervisors and foremen along the top of the chart. Then comes a broad space for the plan, which shows the state and county lines, mile posts, number of tracks (and, by symbols, the weight of rail), sidings, road crossings, bridges (with their numbers), stations, signal towers (with their telegraph calls and the number of the block), etc., with notes as to special rail joints, etc. Below this is the alinement plan, showing the direction and degrees of curves, and symbols on this line indicate the character of the ballast. Below this again is the profile, with rate of grade marked in feet per mile.

A more pretentious chart intended rather for office record or file, used on the New York, New Haven & Hartford Ry. is to the scale of 300 ft. to the inch, with pages 22x10 ins., each showing 5,000 ft. It is divided by verti-

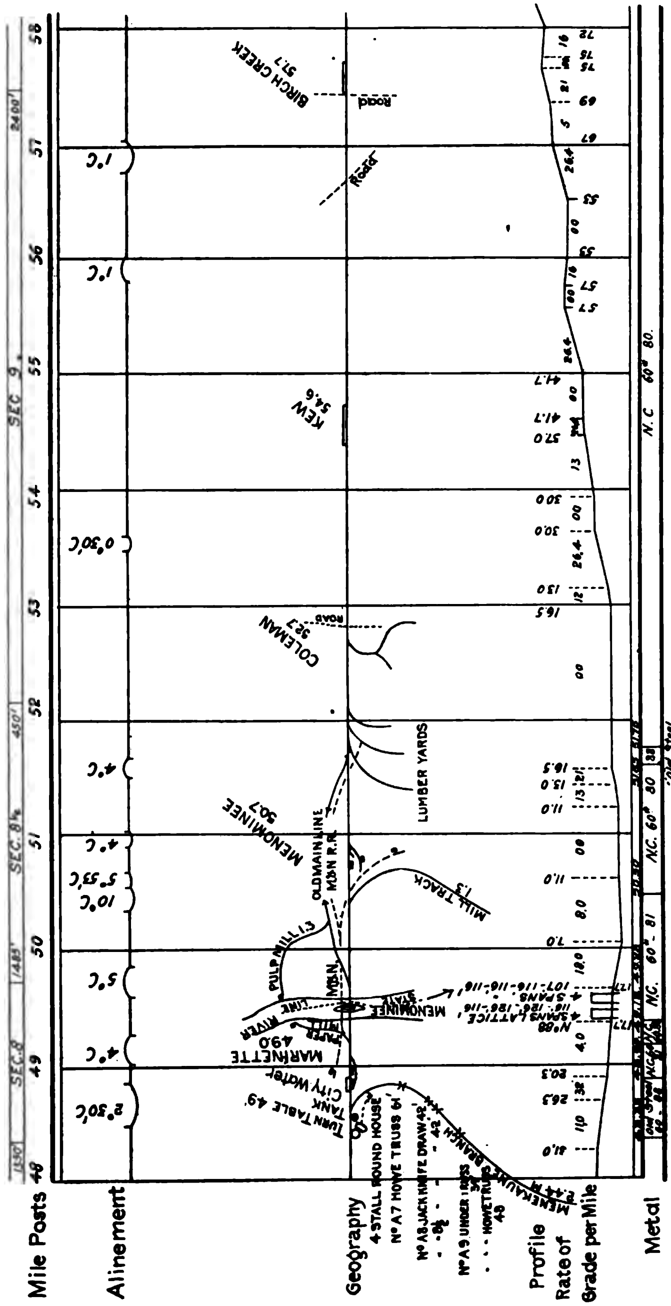


Fig. 227.—Graphical Chart; Chicago & Northwestern Ry.

cal lines making spaces representing 100 ft., and by numerous horizontal lines. It gives in separate lines the names of station agents, trainmen, roadmasters, foremen, etc., landowners, land tax, express and carriage companies at stations, etc. It gives also a track plan, and a profile with signals (including number of blades), switchstands, bridges, signal towers, etc.

Sometimes a record of this kind is in the form of a book. An example of this is a pamphlet report compiled by Mr. W. F. Goltra, Chief Clerk to the Chief Engineer of the Lake Erie & Western R. R., containing right of way tables, a ballast chart, tables of structures, crossings, etc. It is accompanied by full descriptions of standard structures, terminal facilities, weight and age of rails, number and cost of ties, renewals, etc. Loose folding sheets in a pocket of the cover show the plan and profile. Such a report may be yearly corrected to date, supplemented by illustrations of standard structures, and extended indefinitely as desired. It gives very much more detailed information and descriptions than can be put on a chart, but on the other hand a chart possesses certain advantages in itself, especially for use in the railway offices, as it shows at a glance the relative location of various works and the general scope of the equipment.

Reports.—The proper carrying on of the work of the roadway department and the necessity of determining the cost of the work, involves the use of various reports, note books, blanks, etc., and these should be in as few different sizes and styles as possible, so as to insure uniformity and to facilitate filing as records or for reference. Nearly every road has its own

TABLE NO. 38.—TRACK DEPARTMENT REPORTS; L. S. & M. S. Ry.

		Size, ins.	Report made, time.	Prepared by.	Sent to.
1.	Work done and changes made	13¾ × 8¾	M.	S. Foreman	R'dmaster.
2.	Defective rails removed from main track	7 × 8½	"	"	"
3.	Tools and equipment on section	14 × 8½	"	"	"
4.	Tools and equipment on division	14 × 8½	"	R'dmaster	Div. Engr.
5.	New and second hand material on section	15 × 9½	"	S. Foreman	R'dmaster.
6.	New and second hand material on division	15 × 9½	"	R'dmaster	Div. Engr.
7.	Section and fence gang	9½ × 5¾	W.	Foreman.	R'dmaster.
8.	Section and fence gang	9½ × 6	"	R'dmaster	Div. Engr.
9.	Extra gang	9¼ × 5½	D.	Foreman.	R'dmaster.
10.	Excavator	9 × 5¾	"	Engineman	"
11.	Work train	9½ × 6	"	Conductor.	"
12.	Engine service of work train	8½ × 12	M.	"	"
13.	Extra force	8½ × 14	D.	R'dmaster	Div. Engr.
14.	Extra force	9 × 14½	"	Div. Engr.	Chf. Engr.
15.	Gravel and earth handled	8½ × 13	"	R'dmaster	Div. Engr.
16.	Gravel and earth handled	9 × 14½	"	Div. Engr.	Chf. Engr.
17.	Wood	4 × 6½	M.	R'dmaster	Div. Engr.
18.	Ballast	4 × 9	"	"	"
19.	Scrap on hand	4 × 9	"	"	"
20.	Rails used	4 × 9	"	"	"
21.	Side tracks built	7½ × 9½	"	"	"
22.	Side tracks taken up	7½ × 9½	"	"	"
23.	New steel rails laid in main track in renewals	7½ × 9½	"	"	"
24.	2d hand rails laid in main track in renewals	7½ × 9½	"	"	"
25.	Steel rails laid in sidetracks in place of iron	7½ × 9½	"	"	"
26.	Bridge and culvert inspection	8¼ × 13¾	"	"	"
27.	Broken rails found in main track	10¾ × 8½	"	S. Foreman	R'dmaster.
			"	R'dmaster	Div. Engr.
28.	Defective steel rails removed from main tracks (see No. 2)	14 × 8½	"	R'dmaster	Div. Engr.
			"	Div. Engr.	Chf. Engr.

THE LAKE SHORE & MICHIGAN SOUTHERN RAILWAY CO.

ENGINEER'S DEPARTMENT.

Section No. ......, ...(Division or Branch.)

Report of Work Done and Changes Made During Month of ....189....

This blank must be filled out and sent to Roadmaster as soon after end of month as possible. Each item must be answered in some way; if there is no data to report, the words "nothing done" must be written. Section foremen will report results and changes on their sections whether made by themselves or by others. Results accomplished by Extra gangs, Fence gangs, and other Section gangs, as well as by Carpenters, Telegraph linemen, or outside parties must therefore be reported by the various foremen having charge of the sections on which done. Foremen on lines having 2, 3 or 4 main tracks will show which track is referred to by writing its name in the space left for that purpose in certain items.

---

1. New steel rail has been laid in ....main track from Sta.......to Sta.......
   " " " " " " " .... " " " " ...... " ....
2. 2d hand and cut rail has been laid in........ " " " " ...... " ....
   " " " " " " " " " .... " " " " ...... " ....
3. New ballast has been put in .... " " " " ...... " ....
   " " " " " " .... " " " " ...... " ....
4. New ditch has been dug on ....side of track from Sta...... " ....
   " " " " " " .... " " " " " ...... " ....
5. Old ditch has been cleaned on .... " " " " " ...... " ......
   " " " " " " .... " " " " " ...... " ....
6. Stand. cross-sec. been completed on....... " " " " " ...... " ....
   " " " " .... " " " " " ...... " ....
7. New fence has been constructed on....... " " " " " ...... " ....
   " " " " " " .... " " " " " ...... " ....
   " " " " " " .... " " " " " ...... " ....
8. Steel rail has been laid in following named side tracks: ....
....
9. The following new side tracks have been built and old ones extended:.............
....
10. The following side tracks have been taken up and shortened: ....
....
11. Fly rails were changed at following switches: ....
....
12. Frogs were changed at following switches: ....
....
13. Cattle-guards were renewed or repaired at following named crossings: ....
....
14. New obstructions have been erected over tracks at following places: ....
....
15. The following named overhead obstructions have been raised, lowered or removed:
....
16. New obstructions within 6 ft. of track have been put up at following places:......
....
17. The following named side obstructions within 6 ft. of track have been changed or removed: ....
18. All bridges and culverts on this section are in good condition, except the following:
....
....

Remarks: ....
....
....

....Section Foreman.

(Blank No. 1.)

Monthly Report on Section Work; L. S. & M. S. Ry.

series of blanks, and for different purposes, but a list of the principal blanks issued for reports by the engineer's department of the Lake Shore & Michigan Southern Ry. is given in Table No. 38:

Report of Defective Steel Rails removed from Main Tracks on ________________ Division, during month of ________________ 189__

Section Foremen will report on this blank to Roadmaster all rails removed from Main Tracks for any of the causes mentioned below, or for any other failure. This will include rails disabled by wreck, but will not include rails worn out in a ligitimate way after 5 years service. No side track or switch rails are to be reported hereon. Report one rail only on each line.

Removed from		Kind of Rail.				Brand.			Kind of Joint Fastening.							Cause of Removal.												
Section.	Track—North, south, east, west, middle or single main.	Cut.	Uncut.	Length, in Feet.	Weight per Yard.	Mill.	Date Made.		4-hole Fish Plate, Joint on Tie.	4-hole Fish Plate, Joint between Ties.	4-hole Angle Splice, Joint between Ties.	4-hole Angle Splice, Joint on Tie.	6-hole Angle Splice, Joint on Tie.			Broken in Two.	Cracked.	Piece broken out of Head.	Piece broken out of Flange.	Battered and Worn at End.	Dangerous, [illegible] of Flaw.	Burned by Engine Slipping.	Bent in Line or Surface.	Worn out on Curve.	Worn out under ordinary conditions before serving 5 years.	Was failure caused by wreck or broken wheel.	Was rail broken at Bolt Hole.	Did rail show sign of Flaw.

(Blank No. 2.)

Monthly Report on Defective Rails; L. S. & M. S. Ry.

The style of Blanks Nos. 1, 2, 4, 5, 7, 8, 9, 10, 11, 13, 15, 17, 18, 19, 20, 21, 22, 23, 25, 26 and 27 are given herewith, and their sizes are indicated on the list in Table No. 38.

Nos. 3 and 4 are double sheets, folded at the top, with headings as shown, and the various tools and supplies printed under "Kind of Tool," with plenty of blank lines for material not so specified. Nos. 5 and 6 are three-page blanks, bound together at the top, and having printed lists somewhat as in Nos. 3 and 4.

No. 7 is filled out by the foreman of the gang on the 7th, 14th, 21st and last day of each month.

No. 12 has at the left hand a 3½-in. column headed "Account of," and then 31 columns for the number of hours worked each day and a column for the total number of hours for the month.

No. 13; extra men include all those on the roadmaster's rolls, outside of those on section and fence gang rolls. Each gravel pit and piece of important work should be kept separate, and gangs on work trains engaged in ordinary miscellaneous work should be shown as doing such work. No. 14 is similar to No. 15, but has at the left an additional column headed "Roadmaster's Division."

No. 15; the material handled in each piece of second track, change of grade or other important work, as well as in each gravel pit, should be shown separately. Gravel unloaded for ordinary main line ballasting on divisions where such ballast has been received from elsewhere, must be treated likewise. No. 16 is the same as No. 15, but has at the left an additional column headed "Roadmaster's Division."

No. 24 is identical in form with No. 23, and No. 29 is identical in form with No. 2. Nos. 2 and 28 are to show all rails removed from main tracks, including rails disabled by wreck, but not including rails worn out in a legitimate way after five years' service.

A committee of the Roadmasters' Association of America reported in 1894 that the blank forms for Maintenance of Way records should be made up so as to suit the organization and the system of accounts in use on each road; consequently no special recommendation could be given

Monthly Inventory of Tools and Equipment on .... { Branch or Division } for .... 189...

Road Masters will show only new tools in stock, the equipment (or Engineers Dep't tools on wheels) on his Division, and the total number on his territory, of the large tools marked "new and 2d hand." Second hand tools in stock or in the hands of his men are not to be included.

KIND OF TOOL		On Hand ......1st.	Received	Shipped	Used	On Hand ......1st.	KIND OF TOOL		On Hand ......1st.	Received	Shipped	Used	On Hand ......1st.
Axes, Chopping,	New, No. of						Dippers, Drinking	New, No. of					
" Hand,	" "						Drills, Ratchet	" "					
Adzes,	" "						" Frames	" "					
Augers	" "						" Points, 7/8″	" "					
							" " 5/8″	" "					

(Blank No. 4.)

Each Section Foreman must keep careful count of all Second-Hand Material and Scrap, received by **Removal from Track and Right of Way,** as well as that received from Road Master, and show each kind as received in the proper column. All material of every description, both new and second-hand, if fit for use, must be shown.

Monthly Inventory of New and Second-Hand Material On Sec. .... { Branch or Division. } for .... 189...

KIND OF MATERIAL.	On Hand ......1st.	RECEIVED: By Removal from Track and Right of Way.	RECEIVED: From Road Master.	Shipped.	Used.	On Hand ......1st.	KIND OF MATERIAL.		On Hand ......1st.	RECEIVED: By Removal from Track and Right of Way.	RECEIVED: From Road Master.	Shipped.	Used.	On Hand ......1st.
							Frogs, Spring, 4¾″, L. H. 1 in 10,	New, No. of						
							Frogs, Spring, 4¾″, L. H. 1 in 10,	2d Hd. "						
							Frogs, Spring, 4¾″, R. H. 1 in 10.	New, "						

(Blank No. 5.)

Blank Forms for Reports of Tools and Materials; L. S. & M. S. Ry.

Weekly Report of..............*Gang No*.... ....*Div'n,*

for Week ending.......................... ...*189*.....

FOR REGULAR SECTION AND FENCE GANGS ONLY.

Section and fence gang foremen will fill out these blanks on the 7th, 14th, 21st and last day of each month and forward to Road Master. Under "Remarks," should be given amount of other work done not enumerated on the blank, together with necessary explanations or additional data asked for by Road Master.

Number of men now in gang including foreman..

Total days work performed during week, per time book..

What hand and push cars are on hand?..

Have they been examined daily?..

What is their present condition?..

Have frogs and switches been daily examined and repaired?..

Has frog and switch blocking been daily examined and repaired?..

Cross ties put in main tracks..

" " " " new and old side tracks..

North main track surfaced.	From sta.	to sta. ....
South " " "	" "	" " ....
North " " ballasted and completed.	" "	" " ....
South " " " " "	" "	" " ....
New rail laid in .... main track.	" "	" " ....
" " " " .... " "	" "	" " ....
Cut " " " .... " "	" "	" " ....
" " " " .... " "	" "	" " ....

Feet of new ditch dug..

" " ditched cleaned..

" " cross-section made..

REMARKS:..

(Blank No. 7.)

Foreman's Weekly Report of Section and Fence Gangs; L. S. & M. S. Ry.

as to their number or details. It was thought that the blank forms on many roads were more complicated than necessary to secure the end desired, and often secure duplicate or insufficient information. The committee regarded the following information and forms as generally necessary for a

Weekly Report of Section and Fence Gangs..**Div'n,**

For week ending..*189*.....

Road Masters will fill out these blanks and forward to Division Engineer on 8th, 15th, 22d and 1st day of each month.

	Number of.	Number of days work performed including laborers and foremen.
Regular section gangs,		
" fence "		

(Blank No. 8.)

Roadmaster's Weekly Report of Section and Fence Gangs; L. S. & M. S. Ry.

Daily Report of Extra Gang..*Division.*

....*189*....

Extra Gang Foremen should fill out these blanks each night and forward to their superior. The distribution of labor should be taken from sheet or book on which it is kept, the object being to obtain, daily, a record of how much time is being expended on each piece of work or portion of it.

On what piece of work engaged..

No. of days work performed (Exclusive of Teams and Drivers) ....

No. " " **by Teams and Drivers**........................

Total days work performed, per time book..

No. Flat cars of earth or gravel loaded...........**Earth**........**Gravel**.......

No. Gondola " " " ....**Earth**.......**Gravel**.......

No. Dump " " " ....**Earth**.......**Gravel**.......

	UNLOADED.	WHERE UNLOADED.
No. Flat Cars Gravel	....	....
No. Gondola " "	....	....
No. Dump " "	....	....
No. Flat " **Earth**	....	....
No. Gondola " "	....	....
No. Dump " "	....	....

DISTRIBUTION OF LABOR.

..................**days work on**..

Blank No.9.
Daily Report of Extra Gang; L. S. & M. S. Ry.

proper record of the maintenance of way department of any railway, and for securing the proper charges:

A. A daily record of each trackman's work on a subdivision or on a work train, so that his time can be charged to the proper account.

DAILY REPORT OF EXCAVATOR No.______

______________________ *189*

Steam Shovel Engineers should fill out these blanks each night and forward to their superior.

Where located ____________________________________

On what work engaged______________________________

Total days work performed, per time book ______________

Number of Flat Cars loaded__________**Kind of Material**________

" **Gondola** " " __________ " ________

" **Dump** " " __________ " ________

Total time lost____________________________________

Cause of delays:___________________________________

(Blank No.10.)
Daily Report of Excavator; L. S. & M. S. Ry.

B. A daily record of material used on each track foreman's sub-division.

C. A daily record of materials handled by work trains.

D. A track foreman's monthly report of work done and materials used and on hand on his sub-division.

E. A work train foreman's monthly report of work done.

F. A foreman carpenter's monthly report of all materials used and on hand and work done.

G. A monthly report by track foremen and foremen carpenters of tools on hand.

Daily Report of Work Train..Division.

....189....

Work Train Conductors should fill out these blanks each night and forward to their superior.

On what piece of work engaged..

Number of Locomotive..

Number of days work performed, per time book..

		UNLOADED.	WHERE UNLOADED.
No. Flat	Cars Gravel	....	....
No. Gondola	" "	....	....
No. Dump	" "	....	....
No. Flat	" Earth	....	....
No. Gondola	" "	....	....
No. Dump	" "	....	....

No. Flat Cars held in service for next day's use..

No. Gondola Cars held in service for next day's use..

No. Dump " " " " " ....

(Blank No. 11.)

Daily Report of Work Train; L. S. & M. S. Ry.

H. A supervisor's or roadmaster's monthly report of all materials used and on hand and giving the distribution.

I. A supervisor's or roadmaster's report of periodical inventories of material on hand.

J. A track foreman's and supervisor's or roadmaster's report of fires along the right-of-way.

K. A track foreman's or supervisor's or roadmaster's report of stock killed.

DAILY REPORT OF EXTRA FORCE,..DIVISION.

....189.......

This report should be forwarded to Division Engineer daily. "Extra Men" includes all men paid on Road Master's rolls outside of those on Section and Fence Gang rolls. Each gravel pit and each piece of important work, such as a section of second track construction, change of grade, a new yard, or extensive ballasting of old main track, should be kept separate. Gangs or work trains engaged in ordinary miscellaneous work should be shown as doing such.

At What Point, or On What Piece of Work.	Days' Work Performed by Extra Men.					Excavators at Work. Numbers of	Number of Work Trains.	Locomotives. Numbers of	Cars in Service of Work Trains at End of Day.			Remarks.
	Conductors and Brakemen.	Men on Excavator Rolls.	Teamsters with Teams.	All Other Extra Men.	Total.				Flats.	Gondolas.	Dumps.	

(Blank No.13.)

DAILY REPORT OF GRAVEL AND EARTH HANDLED,..................................DIVISION,..189...

This Report should be Forwarded to Division Engineer Daily. The material handled on each piece of Second Track, Change of Grade, or other important work, as well as in each Gravel Pit, should be Shown Separately. Gravel unloaded for ordinary main line ballasting on divisions where such ballast has been received from elsewhere, must be likewise treated.

Loaded								Unloaded or Shipped.							Remarks.
At What Point, or On What Piece of Work.	By What Means, Excavator or Hand.	Gravel.			Earth.			On What Piece of Work, or To What Point.	Gravel			Earth.			
		Flats.	Gondolas.	Dumps.	Flats.	Gondolas.	Dumps.		Flats.	Gondolas.	Dumps.	Flats.	Gondolas.	Dumps.	

(Blank No.15.)

Blank Forms for Reports; L. S. & M. S. Ry.

__________________ *Div.*

WOOD REPORT, Month of __________________ 189__

On Hand 1st.	Sawed.	Received from other Divisions.	Shipped.	USED.						On Hand 1st.
				Loco.	Repair Loco.	Repair Cars.	Elevator Engines.	Water Supply.	R.W.&T.	

(Blank No.17.)

Monthly Report of Wood; L. S. & M. S. Ry.

Ballast Report, ...Division, ...189......

	Feet.	No. of cu. yds. used.	Remarks.
Old main track ballasted with new gravel..	....	....	....
Old main track ballasted with cinders.....	....	....	....
Old side tracks ballasted with new gravel..	....	....	....
Old side tracks ballasted with cinders......	....	....	....

....Roadmaster.

(Blank No. 18.)

Monthly Report of Ballasting; L. S. & M. S. Ry.

Scrap on Hand, ...1st, 189...... ....Division.

Steel Rails, less than 3 ft. long	....	Gross Tons.
" " 3 ft. long and over	....	" "
Iron Rails, American	....	" "
" " English	....	" "
Booth Rails, ...	....	" "

....Roadmaster.

(Blank No. 19.)

Monthly Report of Scrap; L. S. & M. S. Ry.

Tonnage Report, ...189....... ....Division.

	Feet of rail.	Weight per yard.	Gross tons.
New Steel Rail used in construction of second track.....	....	....	....
2d hand Steel Rail used in construction of second track...	....	....	....
New Steel Rail used in main track renewals	....	....	....
2d hand Steel Rail used in main track renewals.........	....	....	....
New Steel Rail used in new and old side tracks...........	....	....	....
2d hand Steel Rail used in new and old side tracks......	....	....	....

....Roadmaster.

(Blank No. 20.)

Monthly Report of Rails Used; L. S. & M. S. Ry.

L. A track foreman's (also supervisor's or roadmaster's) report of broken rails.

M. A supervisor's or roadmaster's report of scrap for sale.

N. Statement covering shipment of rail and other maintenance of way or construction material.

O. Supervisor's or roadmaster's report of track laid or changed.

Among the most important of these reports are the weekly reports made by the section foremen, showing the details of work done on the sections. By these the roadmaster can keep in touch with the maintenance work

NEW SIDE TRACKS CONSTRUCTED, ________ Division ________ 189__

AT WHAT STATION.	NAME OF TRACK.	LOCATION BY STATION STAKES.		FEET OF TRACK CONSTRUCTED.	REMARKS.
		FROM	TO		

(Blank No. 21.)

SIDE TRACKS TAKEN UP, ________ *Division,* ________ *189*__

AT WHAT STATION.	NAME OF TRACK.	FEET OF TRACK TAKEN UP.	KIND OF RAIL.	KIND OF SWITCH REMOVED, IF ANY.	REMARKS.

(Blank No. 22.)

NEW STEEL RAIL LAID IN MAIN TRACK FOR RENEWALS, ________ Division, ________ 189.

LOCATION BY STATION STAKES.		FEET OF TRACK LAID.	BRAND.			NUMBER OF RAILS LAID OF EACH LENGTH.	REMARKS.
FROM	TO		MANUFACTURE.	Month	Year.		

(Blank No. 23.)

STEEL RAIL LAID IN SIDE TRACKS IN PLACE OF IRON ________ *Division* ________ *189*__

AT WHAT STATION.	NAME OF TRACK.	Feet of Track.	REMARKS.

(Blank No. 25.)

Road-Master's Bridge and Culvert Inspection on ________ {Branch of Division.} during ________ 189__

Having made a careful personal inspection of Bridges and Culverts on this line within......days of date, I find all to be in good condition, except those enumerated below.

Class and Number.	Kind of Structure.	Date of Inspection.	Condition.	REMARKS.

(Blank No. 26.)

Blank Forms for Reports; L. S. & M. S. Ry.

on the whole line and see how the men are getting along, besides knowing what sections need special attention at the first opportunity. The blank may be in book form, the first page having columns for the month, day, number of men, number of hours worked, location of work (by mile and station) and about a third of the page for describing the kind of work. In the lower left hand corner may be a space for the number of ties received, used and on hand at the end of the week and month; in the larger space for remarks are entered the dates of completing special work, and notes of materials or tools needed.

REPORT OF BROKEN RAILS FOUND IN THE MAIN TRACK.

Whenever a broken rail is found in the Main Track, a report should be sent to the Division Engineer by the Roadmaster as soon as possible after a careful investigation has been made.

About a foot of the rail on each side of the break should be cut off and stored away, properly labeled and numbered, so that the fracture may be inspected at any future time.

Date ....

Time of day or night..

By whom ....

Where located (approximate distance east or west of nearest Passenger Station)........

....

Brand of rail (maker and year) ....

Heat mark ....

Length of rail ....

Was it a cut rail or not? ....

Kind of joint fastening ....

Description of break, stating how far from end of rail ....

....

....

Did it occur between ties or on top of tie?..

Approximate temperature of atmosphere when found..

When had track been last patrolled? ....

What is label number of stored pieces?..

Cause of break, if known ....

....

....

....

....Roadmaster.

(Blank No. 27.)

Monthly Report of Broken Rails; L. S. & M. S. Ry.

In preparing forms of reports for use by the foremen, it must be recognized that the men are apt to be but poorly educated and not well fitted for doing much literary work. For these reasons the reports should be simple and plain, as complex reports inaccurately filled out are merely a waste of time, since they are practically valueless. The foremen should be required to fill in their reports with their own hands, and not have station agents or others do this, as there will be less liability to error and it will serve to educate the foremen in the proper method of keeping the reports. These reports are usually in book form, but some roads prefer sheets, as giving space for a greater number of items, the reports being filled up from the totals in the daily time book. In some cases the fore-

man is left to fill in the kind of work, but as a rule there are numerous columns, the headings of which are the different classes of work, and the foreman fills in the number of hours for the particular kind of work done each day by each laborer, there being a page for each man. At the back of the book may be a page for the material received, used and on hand, the latter amount being entered in the new book at the beginning of each month. The columns are footed up at the end of each month and sent to the roadmaster.

The form of time book used by the Pennsylvania Ry. is shown on the next page. The record occupies the two opposite pages of an oblong book, 8½ × 6¼ ins., having 50 double pages, and being-bound in limp leather. This book, properly signed by the foreman, must be returned on the last day of each month to the supervisor, who examines it, certifies if correct, and forwards it to the office of the assistant engineer, where the check rolls are made out. The last columns—"Total Amount Due" and "Chargeable to"—are left blank by the foreman to be filled in by the supervisor.

Where a time-book is divided into columns for the different classes of work the principal items are usually the following:

General repairs to track,
Putting in ties,
Laying rails,
Ballasting,
Surfacing,
Ditching,
Repairing fences,
Repairing telegraph,
Putting in sidetrack,
Switch work.

A monthly time book arranged in this way is used by the Chicago & Northwestern Ry., and the form of page is also shown on page 414. The book is upright, 8¼ × 5¼ ins., with stiff paper covers and seven double pages. It is entitled "Distribution of Track Labor for Section No.——:" the exact location of the section is entered on the cover, or if the book is used for a train, gravel pit or quarry, the name of same must be entered. On the inside of the cover are printed the following instructions to the track foremen in reference to the distribution of labor in the book:

The total number of hours worked should be entered in the first column, headed "Total Time Worked." Following this, columns are provided for distributing the labor under the different headings, and track foremen are required to enter under such headings the number of hours chargeable to each as follows:

General Repairs to Track.—Enter the time consumed in cutting and repairing rails, repairing side tracks, taking up sidings, surfacing track and all other ordinary repairs not enumerated below.

Laying Ties.—Enter the time used in taking up and disposing of old ties, and unloading, handling and laying new ties to replace those taken up.

Laying Rails.—Enter the time consumed in removing and disposing of rails from track and replacing same with other rails: also the ordinary surfacing of the track at the time the rails are laid, and loading the old rails to be sent away.

Ditching.—Enter the time used in opening, clearing, widening and perfecting ditches and drains, and cutting down or strengthening embankments.

Freshet Repairs.—Enter the time consumed in repairing damages to roadway and track caused by freshets.

Track Watchmen Necessitated by Repairs.—Enter the time of men engaged as watchmen and flagmen while repairs of track are in progress and rendered necessary by such repairs.

Ballasting.—Enter the work done in gravel pits, hauling gravel and stone for use in track, quarrying and breaking stone for ballast, raising and repairing track with ballast. (Note,—Gravel train conductors and

foremen of gravel pits and quarries must, in all cases, state on what division, sub-division and section of road the gravel or ballast is to be used, so that the expenses may be properly charged.)

Clearing Track of Snow and Cutting Weeds, Brush and Grass.—This includes clearing same from the roadway and track, etc., and moving and burning weeds, brush and grass inside of fences.

Repairs of Fences, Road Crossings and Signs.—Enter the time consumed in repairing and rebuilding fences, road crossings and signs.

Flagmen.—Enter the time of men engaged as flagmen at crossings.

ACCOUNT OF TIME WORKED for the Pennsylvania Railroad Company during the

NAMES.	HOW EMPLOYED.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1																			
2																			
20																			

I certify that the persons to whose names time is affixed have been diligently employed, during the time specified, in the service of the Pennsylvania Railroad Company.

Foreman.

Section Foreman's Time Book Used on

Repairs of Bridges and Culverts.—Enter the time consumed in repairing or strengthening bridges and culverts.

Bridge Watchmen Necessitated by Repairs.—Enter the time of men engaged as watchmen and flagmen while repairs of bridges or culverts are in progress and rendered necessary by such repairs.

Repairs of Cattle Guards.—Enter the time consumed in repairing and renewing cattle guards.

Reloading Freight, Getting Cars on Track, Etc.—This account includes

[SEE NEXT PAGE.]

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WORK Performed in the Month

Occupation________________________

DATE.	Total Time Worked.	"REPAIRS OF ROADWAY AND TRACK."								"Repairs of Fences."
		General Repairs Track.	Laying Ties.	Laying Rails.	Ditching.	Freshet Repairs.	Track Watchmen necessitated by repairs.	Ballasting.	Clearing Track of Snow and Cutting Weeds and Grass.	Repairing Fences, Road Crossings and Signs.
1										
2										
3										
31										
Total No. of Hours.										
Total Am't of Wages.										

Section Foreman's Time Book Used on

time occupied in watching and reloading freight into cars and getting cars on the track when wrecked or disabled. It also includes time consumed in picking up lumber or other freight lost from cars along the line. (Give particulars in each case.)

Station Labor.—Enter in this column labor assisting at stations in loading and unloading freight or performing other station labor, such as attending to switches. (Give name of station in each instance, and kind of work done.)

Maintaining Telegraph.—Enter the time devoted to repairing or looking after telegraph lines.

Construction of Sidings.—Enter the time consumed in grading and laying new side tracks and lengthening and extending old sidings.

Remarks.—Enter in this column such items or charges as do not properly belong under the headings provided, as specified above, stating in every case the nature of the work and where it was done; also if a time ticket has been given, enter the particulars in this column.

The time of Track Foremen, Conductors of gravel trains and Foremen

Month of __________ 189__ __________ DIVISION, Subdiv. No. ____

19	20	21	22	23	24	25	26	27	28	29	30	31	Time Worked. Mo.	Time Worked. Hrs.	Rate of Pay. Dolls.	Rate of Pay. Cts.	Total Am't Due. Dolls.	Total Am't Due. Cts.	CHARGEABLE TO		

Examined and found correct,

Supervisor *Total Amount, $* *Total Amount of Check Roll, $*

the Pennsylvania Ry.

of gravel pits should be distributed herein each day in the same manner as track laborers.

Enter the distribution of labor in this book in a plain, legible manner, at the close of each day's work, and oftener when necessary. At the close of the month add up each column and enter the footings at the bottom of the column, opposite the word "Totals," being careful to see that the footings of all the distribution columns (when added together) agree with the footings of the column headed "Total Time Worked."

[SEE PRECEDING PAGE.]

of________________ 189__, By________________

Rate, $__________ per__________

	"Flagmen."	"Watchmen."	"Repairs of Bridges and Culverts."		"Repairs of Cattle Gds."	"Laborers."		"Maintaining Telegraph."	"Construction of Sidings."	REMARKS.
	Flagmen at Crossings.	Bridge and Track Watchmen.	Repairing Bridges and Culverts.	Bridge Watchmen Necessitated by Repairs.	Repairing Cattle Guards.	Reloading Cars, Getting Cars on Track, etc.	Station Labor.	Repairing Telegraph.	New Side Tracks.	
										Grand Total, $____

the Chicago & Northwestern Ry.

This book must be sent forward promptly, as directed, on the night of the last day of the month.

Cost of Railway Maintenance Work.—This is so large a proportion of the total cost of operation that it is most important, in the interests of economy, that full and accurate records should be kept of the details of work done, the material consumed, and the cost of the various items of work and material. As such records must be based mainly on the returns and

reports of the section foreman, it is essential that such returns and reports should be so designed as to give all necessary information with the least possible work on the part of these men, and with the lowest possible chance for error on their part. This matter has been dealt with very clearly by Mr. Marshall M. Kirkman, Vice-President of the Chicago & Northwestern Ry., in his pamphlet on "The Track Accounts of Railways." His plan is, in brief, to have the final records attained in two distribution books or statements, one being for labor and the other for material. These are posted up by the superintendent monthly from the foremen's books, and show all track expenditures, and the accounts to which such expenditures are properly chargeable. At the general office a "track material" account is kept with each division superintendent. In the superintendent's book the average cost per mile for repairs of track and roadway is obtained by summing up the total number of hours worked on each subdivision, and taking a full day's work for each man for the entire month.

During construction and maintenance, careful notes should be made and records kept and tabulated to show the work done, time occupied, tools and materials used, items of cost, etc. The regular reports should show the number of men engaged on each particular item and class of work, and the character and amount of materials used. All work of this kind, which puts figures on record and enables comparisons to be made, and the relations between work, expenditure and results to be comprehended, tends toward the improvement of work and methods. Proper financial accounts of all expenditures for maintenance and renewals and betterments should also be made. In the annual estimates some railways allow to each division a certain amount for track work, but the appropriation for betterments or construction should be entirely separate from that for maintenance.

Instruction Books.—The work of the roadmasters and section foremen, who are the men in actual charge of the track, carries a considerable responsibility, and the most thorough means should be taken to keep these men fully informed as to their duties, and to impress upon them that the safe and proper condition of the track is the first and most important consideration. An excellent plan is to issue "instruction books," similar to those already in use on some roads, but which should be more extensively adopted. For a road starting to adopt this plan, the books should at first be small pamphlets, so as not to incur much expense, and after they have been in service for a sufficient time to become well known and well used, opinions and suggestions should be invited from time to time from the men on the road and from officers of other roads in order that improvements may be made by eliminations, alterations and additions, so as to embody the best results of actual experience. A handy book can then be made up for permanent use. The matter should be clearly and concisely written (care being taken to avoid ambiguous phraseology, involved sentences or words not commonly used) so as to be readily understood, and the use of diagrams will add to the usefulness of the book. It should be clearly printed on strong paper, and strongly bound. The illustrations should preferably be on the pages of the book, or at any rate on sheets not folded more than once or twice, as large folding sheets are awkward to handle and are liable to be very soon torn. Special instructions should

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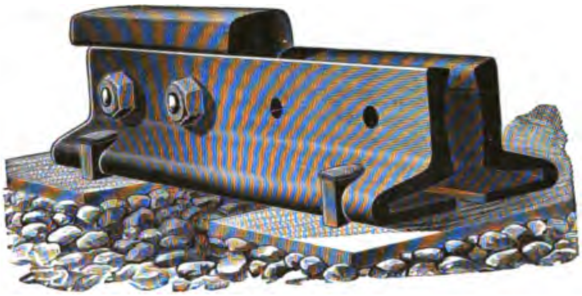

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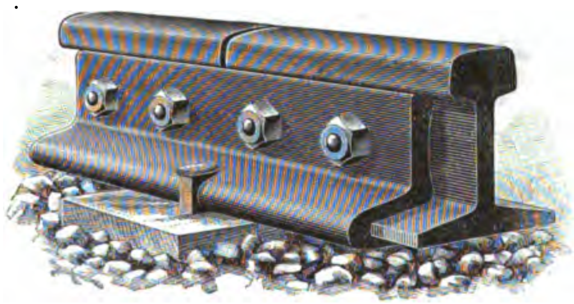

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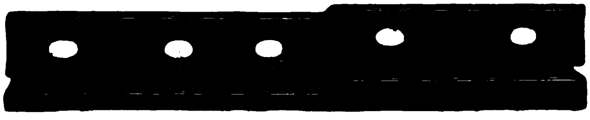

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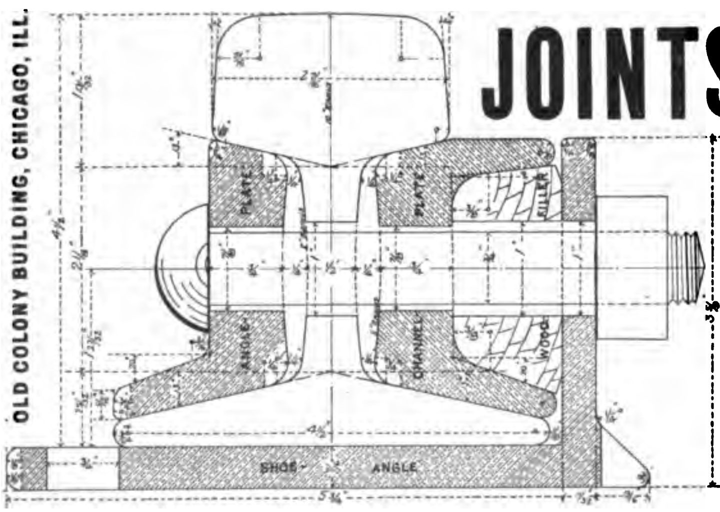

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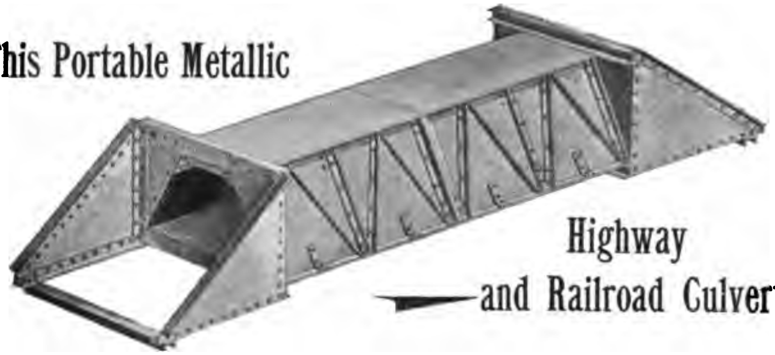

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